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**A Technical and Economic
Evaluation of the Project in
Baltimore, Maryland. Volume III**

Systems Technology Corp, Xenia, OH

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Jun 79

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A Technical and Economic Evaluation Of the Project In Baltimore, Maryland

Volume III

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This report is a complete technical, economic, and
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A TECHNICAL AND ECONOMIC EVALUATION OF THE
PROJECT IN BALTIMORE, MARYLAND

Volume III

This report (SW-175c) describes work performed
for the Office of Solid Waste under contract no. 68-01-4359
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1979

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PREFACE

This report is a complete technical, economic, and environmental evaluation of the Landgard® Demonstration Plant at Baltimore, Maryland. Because of its bulk and to serve a twofold purpose, the report is presented in four volumes: an executive summary, the report proper, an analysis of the problems, and the appendices. Intended particularly for resource recovery planners and administrators, the executive summary briefly and succinctly describes the Landgard® concept and Baltimore application for the state-of-the-art advancement in the processing of municipal mixed solid waste. In addition, it presents an introductory problem analysis of most of the major innovations that proved ineffective, caused serious shutdowns, and required redesign or abandonment. As the second, third, and fourth volumes are detailed in-depth accounts of the evaluation, they were prepared primarily for the designer. Of the four volumes, only the executive summary has been prepared for wide distribution in a paper copy format. The second, third, and fourth volumes are reproduced on microfiche, which is readily available through NTIS.

ABSTRACT

One of the first efforts in this country to demonstrate solid waste resource recovery technology was the Baltimore Landgard® project which was a joint venture between the City of Baltimore, the U.S. Environmental Protection Agency (EPA), the Maryland Environmental Service, and Monsanto EnviroChem. The Baltimore plant was designed and built by Monsanto EnviroChem to thermally process (pyrolyze) 907 Mg (1000 tons) per day of mixed municipal solid waste, convert it to energy (in the form of steam), and recover magnetic metals and glassy aggregate. Although the plant has never been fully operational in its original design configuration, considerable knowledge has been gained from it concerning resource recovery from municipal solid waste. The numerous equipment breakdowns and the inability of the plant to comply with air pollution standards accounted for the major difficulties encountered during the project. Major equipment problems were encountered with the storage and recovery unit, the refractory in the thermal processing vessels, the main induced-draft fan, the residue discharge drag conveyor, and the slag discharge screw conveyor. Despite the fact that the designer recommended converting the plant to a conventional incinerator, plant performance has been sufficiently encouraging to warrant continued investment and operation by the City of Baltimore. One of the primary reasons for this attitude by the City is that the rotary processing kiln has been demonstrated to be an excellent primary reaction vessel. Although the present plant is not environmentally acceptable because of high particulate emissions, this problem will be resolved by the installation of two electrostatic precipitators.

The thermal efficiency of the plant was determined to be approximately 56 percent for an average feed rate of 454 kg per minute (30 tph). The plant has a capital cost of approximately \$22 million, an annual operating and maintenance cost of \$3 million, and an annual steam revenue of \$1 million. The net operating cost, based on historical operating data, is \$64.10 per Mg (\$58.20 per ton) of refuse processed. However, if the annual throughput of 67,000 Mg (74,000 tons) could be substantially increased to 270,000 Mg (300,000 tons), operating cost could be reduced to \$7.80 per Mg (\$7.10 per ton) of refuse processed.

This report is submitted in fulfillment of Contract No. 68-01-4359 by Systems Technology Corporation (SYSTECH) under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1, 1975 to April 30, 1978.

CONTENTS

Preface	i
Abstract	ii
Figures	iv
Tables	vi
List of Unit Conversions	xiv
List of Symbols	xv
Acknowledgement	xvii
Appendices	
A. Kiln model description	1
B. Mass and energy balance	18
C. Economic evaluation	234
D. Kiln model computer program	369

FIGURES

<u>Number</u>		<u>Page</u>
A-1	Simplified Kiln Flow Diagram	3
A-2	Mass Flow Relative to the Rotary Kiln	4
A-3	Model of Mass Flow Through the Kiln	6
A-4	Mass Fluxes Through Lower Elements	7
A-5	Energy Fluxes in the Lower Elements	9
A-6	Mass Fluxes Through Upper Elements	10
A-7	Energy Fluxes in the Upper Elements	12
A-8	Finite Element Numbering Scheme	13
A-9	Computer Program Flow Diagram	15
B-1	Photo Sort Picture	40
B-2	Refuse Size Distribution	57
B-3	Anemometer Calibration Curve	71
B-4	Refuse Combustion Air Fan Field Fan Curve	81
B-5	Turbine Driven Kiln Combustion Air Fan Field Fan Curve	82
B-6	Motor Driven Kiln Combustion Air Fan Field Fan Curve	83
B-7	Gas Purifier Combustion Air Fan Field Fan Curve	84
B-8	Crossover Combustion Air Fan Field Fan Curve	85
B-9	Refuse Combustion Air Fan Curves	86
B-10	Turbine Driven Kiln Combustion Air Fan Curve	87
B-11	Motor Driven Kiln Combustion Air Fan Curve	88
B-12	Gas Purifier Combustion Air Fan Curve	89

Figures (continued)

<u>Number</u>		<u>Page</u>
B-13	Gas Purifier Combustion Air Fan Curves	90
B-14	Crossover Combustion Air Fan Curves	91
B-15	Crossover Combustion Air Fan Curves	92
B-16	Flow Through Slotted Quench Damper (100% open)	94
B-17	Flow Through Butterfly Quench Damper	96
B-18	Kiln Skin Temperature Profile	98
B-19	Kiln Skin Temperature Profile	99
B-20	Kiln Skin Temperature Profile	100
B-21	Kiln Skin Temperature Profile	101
B-22	Kiln Skin Temperature Profile	102
B-23	A Combined-reverse Static Pitot Tube	103
B-24	Standby Test Mass Balance	104
B-25	Standby Test Energy Balance	171
B-26	On-steam Test Mass Balance	172
B-27	On-steam Test Energy Balance	173
B-28	Scrubber Solids Settling Curves	194

TABLES

<u>Number</u>		<u>Page</u>
B-1	Total Plant Electrical Energy Demand	21
B-2	Receiving Module Electric Power Demand	22
B-3	Size Reduction Module Electric Power Demand	22
B-4	Storage and Recovery Module Electric Power Demand	23
B-5	Thermal Processing Module Electric Power Demand	24
B-6	Residue Separation Module Electric Power Demands	25
B-7	Energy Module Electric Power Demand	25
B-8	General Plant Module Electric Power Demand	26
B-9	Water Consumption	27
B-10	Analysis of City Water	28
B-11	Wastewater Effluent Flow Measurements	30
B-12	Steam, Water and Sewer	35
B-13	Temperature and pH of Wastewater Effluent	36
B-14	Analysis of the Wastewater Effluent	38
B-15	A Comparison of Manual and Photo Sort	41
B-16	Manual Sort of Refuse Fines	43
B-17	Baltimore Refuse Average Component Properties	44
B-18	Shredded Refuse Moisture Content	45
B-19	Proximate Analysis of Refuse	46
B-20	Ultimate Analysis of Refuse	49

Tables (continued)

<u>Number</u>		<u>Page</u>
B-21	Calculated Refuse Composition	50
B-22	Ash Analysis of Refuse	51
B-23	Optical Emissions Spectrography Analysis of Feed Sample . .	52
B-24	Refuse Bulk Densities	53
B-25	Refuse Bulk Densities	54
B-26	Refuse Bulk Densities After Shredding and Storage	55
B-27	Baltimore Refuse Size Distribution	56
B-28	Diesel Fuel Consumption While Processing	58
B-29	Diesel Fule Consumption During Downtime	58
B-30	Dust Collection System Flows	60
B-31	Composition of Magnetic Drum Discharge	61
B-32	Atlas Runout Data	62
B-33	Operation Summary	64
B-34	Daily Fuel Oil Consumption	70
B-35	Standby Hourly Fuel Oil Consumption	72
B-36	Operating Hourly Fuel Oil Consumption	73
B-37	Analyses of No. 2 Fuel Oil	76
B-38	Propane Consumption	78
B-39	C18 Fan Flow Measurements	93
B-40	Gas Purifier Skin Temperature	108
B-40a	Feedhood Orstats	114
B-41	Feedhood Particulate Loadings	115
B-42	Particle Size Analysis of Feedhood Particulate	116

Tables (continued)

<u>Number</u>		<u>Page</u>
B-43	Ultimate Analysis of 4 Buell Filters and Sample Collected from Feed Hood	117
B-44	Ultimate Analysis of Feed Hood Particulates	117
B-45	Spectrographic Analysis of 4 Buell Filters and Sample Collected from Feed Hood	118
B-46	Spectrographic Emission of Feed Hood Particulate	119
B-47	X-ray Diffraction Analysis of Feed Hood Composi Particulate	120
B-48	X-ray Diffraction Analysis of Feed Hood Particulate	121
B-49	X-ray Fluorescence Analysis of Feed Hood Particulate Sample Collected 5/27/75	122
B-50	X-ray Fluorescence Analysis of Feed Hood Particulate Collected 6/28/78, 1435 HRS.	122
B-51	Mass Spectrometric Analysis of Kiln Off-Gas	123
B-52	Total Hydrocarbon Analysis of Kiln Off-Gas	124
B-53	Crossover Duct Orstats	125
B-54	Flame Ionization Detection Analysis of Crossover Duct Gases	127
B-55	Thermal Conductivity Analysis of Crossover Duct Gases . . .	128
B-56	Long Chain Hydrocarbon Analysis of Crossover Duct Gases . .	128
B-57	Total Hydrocarbon Analysis of Gas Purifier Exit Gases . . .	130
B-58	Mass Spectrographic Analysis of Gas Purifier Exit Gases . .	130
B-59	Gas Purifier Discharge Duct Orstats	131
B-60	ESP Results for Gas Purifier Exhaust Gases Passed Through a Gas Cooler	132
B-61	Boiler Inlet Orstats	133
B-62	Boiler Outlet Orstats	134

Tables (continued)

<u>Numbers</u>		<u>Page</u>
B-63	Moisture Content of Boiler Exit Gases	135
B-64	Dry ESP Test of Boiler Exit Gases	136
B-65	Ash Analysis of Boiler Exit Gas Particulate	138
B-66	Residue Weight Calculations	140
B-67	Residue Weight Calculations	140
B-68	Residue Moisture Content and Bulk Density	141
B-69	Proximate Analysis of Residue	142
B-70	Ultimate Analysis of Residue	147
B-71	Ash Analysis of Residue	148
B-72	Residue Size Distribution	150
B-73	Refuse Ash Fusion Temperatures	151
B-74	Residue Ash Fusion Temperatures	151
B-75	Gasoline Consumption While Prodcessing	152
B-76	Gasoline Consumption During Downtime	152
B-77	Analysis of Residue Quench Tank Process Water	153
B-78	Analysis of Residue Truck Drainage	154
B-79	Slag Weight Calculations	155
B-80	Slag Moisture Content and Bulk Density	156
B-81	Ash Analysis of Gas Purifier Slag	157
B-82	Slag Size Distribution	159
B-83	Slag Ash Fusion Temperatures	160
B-84	Analysis of Slag Quench Tank Process Water	162
B-85	Fly Ash Weights	163

Tables (continued)

<u>Numbers</u>		<u>Page</u>
B-86	Boiler Fly Ash Fusion Temperatures	163
B-87	Boiler Water Analysis	166
B-88	Monsanto Energy Balance Summary	176
B-89	Mass Spectrophotometric Analysis of Gas Sampled at the Scrubber Inlet	179
B-90	Scrubber Inlet Particulate Loadings	180
B-91	Anderson Particle Size Distribution of Scurbber Inlet Gases	181
B-92	Electron Probe Micro Analysis of Scrubber Inlet Particulate	182
B-93	Caustic Consumption	183
B-94	Temperature of Scrubber System Process Waters	184
B-95	Solids Content of Scrubber Process Waters	185
B-96	Emission Spectrographic Analysis of Scrubber System Process Waters and Their Filterable Solids	195
B-97	Analysis of Scrubber Process Waters	196
B-98	pH of Scrubber Process Water and Dehumidifier Condensate . .	197
B-99	pH of Scrubber System Process Waters	200
B-100	Corrosion Rates Based on Ultrasonic Measurement	201
B-101	Evaluation of Alloys for Incinerator Scrubbers	202
B-102	Flocculant Efficiencies	203
B-103	Clarifier Efficiency	204
B-104	Spark Source Mass Spectrometric Analysis of Scrubber Inlet and Exit Particulate	205
B-105	Nitrous Oxide Emission Data	206
B-106	Scrubber Outlet Orsats	207
B-107	Mass Spectrophotometric Analysis of Scrubber outlet Gas . .	208
B-108	Analysis of Boiler and Scrubber Outlet Gases	209

Tables (continued)

<u>Numbers</u>		<u>Page</u>
B-109	Moisture Content of Scrubber Outlet Gases	211
B-110	EPA Method 5 Particulate Loadings of Scrbber Outlet Gases	212
B-111	Anderson Particle Size Analysis of Scrubber Outlet Gases .	213
B-112	BMS-11 Particulate Size Analysis of Scrubber Outlet	220
B-113	Analysis of Scrubber Outlet Particulate	221
B-114	Electron Probe Micro Analysis of Scrubber Outlet Particulate	222
B-115	Dehumidifier Bay Temperature and Velocity Data	223
B-116	Mass Spectrophotometric Analysis of Dehumidifier Gases . .	224
B-117	Anderson Particle Size Analysis of Dehumidifier Ministack .	225
B-118	Electron Probe Micro Analysis (E.P.M.) of Dehumidifier Particulate	227
B-119	Dehumidifier Condensate Flow	228
B-120	Analysis of Dehumidifier Condensate	229
B-121	Moisture Content of Various Residue Recovery Process Streams	230
B-122	Solids Analysis of Various Residue Recovery Process Streams	231
B-123	Proximate and Ultimate Analysis of Char	232
B-124	Proximate and Ultimate Analysis of Glassy Aggretates . . .	233
C-1	Research Summary Capital Expenditure Extract as of 3/31/77	244
C-2	A Summary of EPA Capital Cost Classifications	246
C-3	Summary Cost Center Distributions	247
C-4	1977 Dollar Conversion Factors	251
C-5	Capital Costs (Exclusions/Additions)	252
C-6	Equipment Costs and Useful Life Reported by Select Vendors	253
C-7	Projected Scenario Capital Cost Summary	254

Tables (continued)

<u>Numbers</u>		<u>Page</u>
C-8	Exclusions/Additions Per EPA Cost Center	256
C-9	Capital Costs Per EPS Cost Center Including Adjustments . .	257
C-10	Subsystem Capital Costs	258
C-11	Normalized Scenario Capital Costs Summary	259
C-12	Scenario Operating Parameters	261
C-13	Operating & Maintenance Unit Cost Data	263
C-14	Annual Salries (FY 1977-78)	266
C-15	Total Scenario Salary Costs	267
C-16	Scenario Fuel Costs	267
C-17	Estimated Electrical Demand	268
C-18	Projected Maintenance Costs	270
C-19	Annual Residue Disposal Costs	272
C-20	Indirect City Cost Allocation	274
C-21	Other Overhead Costs	275
C-22	Projected Annual Operating and Maintenance Costs	276
C-23	Projected Annual Operating and Maintenance Costs per Mg of Refuse Processed	277
C-24	Operating and Maintenance Costs per Cost Center (Scenario 1)	278
C-25	Fixed vs. Variable Operating and Maintenance Costs	281
C-26	Normalized Annual Operating and Maintenance Costs	282
C-27	Projected Cost Summary	285
C-28	Normalized Cost Summary	286
C-29	Capital Costs - Actual (Costs in 19__ \$)	289

Tables (continued)

<u>Number</u>		<u>Page</u>
C-30	Annual Operating and Maintenance Costs - Actual (Cost in 19__ \$)	290
C-31	Product Revenues - Actual (Revenues in 19__ \$)	291
C-32	Capital Cost - Normalized (Cost in 1975 \$)	292
C-33	Annual Operating and Maintenance Costs - Normalized (Cost in 1975 \$)	293
C-34	Product Revenues - Normalized (Revenue in 1975 \$)	294
C-35	Summary (\$ Per Throughput Ton)	295
C-36	Actual Capital Costs	304
C-37	Actual Annual Operating and Maintenance Costs	307
C-38	Allocation and Identification of Supplemental Construction Costs	309
C-39	Allocation of Landfill Costs	317
C-40	Monsanto Cost Coding Definitions	319
C-41	Major Equipment List	320
C-42	Original Contract Costs	324
C-43	Original Contract Capital Costs	340
C-44	Non Specific Costs	358
C-45	Original Contract Capital Costs by Cost Center	359
C-46	Supplemental Agreement Capital Costs by Cost Center	367

LIST OF UNIT CONVERSIONS

ENGLISH EQUIVALENTS

SI

DESCRIPTION

DESCRIPTION	UNIT	SYMBOL	UNIT	SYMBOL
LENGTH	meter	(m)	3.28 feet	(ft)
	centimeter	(cm)	0.394 inches	(in)
	millimeter	(mm)	39.37 mils	
	micrometer	(μ m)	1.0 micron	
AREA	square meter	(m^2)	10.76 square feet	(ft^2)
VOLUME	cubic meter	(m^3)	35.31 cubic feet	(ft^3)
	liter		0.264 gallons	(gal.)
MASS	kilogram	(kg)	2.20 pounds	(lbs.)
	megagrams	(Mg)	1.10 tons	
PRESSURE	kilopascal	(kPa)	0.145	(lbs./in ²)
TEMPERATURE	celsius	(C)	5 fahrenheit/9-17.8	(F)
ENERGY	joule	(J)	9.48 $\times 10^{-4}$	(Btu)
DENSITY		(kg/m ³)	.0624	(lbs./ft ³)
ENERGY/MASS		(MJ/kg)	431	(Btu/lb.)
MASS LOADING		(g/DSCM)	0.437	(gr/DSCP)
CONCENTRATION		(μ l/l)	1.0	(ppm)
POWER	kilowatt	(kw)	0.06	(MJ/min)

LIST OF SYMBOLS

A_{IX}	Inlet Area for Fan X (m^2)
A_S	Surface Area (m^2)
C	Constant
D	Duct Diameter (m)
e/D	Ratio of Duct Surface Roughness to Duct Diameter
E_ℓ	Line Voltage (volts)
f	Flow Resistance Coefficient
F_{GP}	Gas Purifier Fuel Oil Heat Input (MJ/ ℓ)
F_K	Kiln Fuel Oil Flow Rate (ℓ /min)
F_M	Main Totalizer Differential Readings/Unit Time (ℓ /min)
F_{12}	Totalizer Differential Readings For #1 and #2 Burners/Unit Time (ℓ /min)
g	Gravitational Constant (m/sec^2)
Gr	Grashof Number
h	Steam Enthalpy (MJ/kg)
h_A	Enthalpy of Dry Air at Fan X Inlet (kg/min)
h_C	Convective Heat Transfer Coefficient $\frac{(BTU}{ft^2 min^\circ R}$ or $\frac{MJ}{m^2 min^\circ K}$)
h_{CI}	Duct Internal Convective Heat Transfer Coefficient
h_{CO}	Duct External Convective Heat Transfer Coefficient
h_{CW}	Enthalpy of Inlet Cold Water (MJ/kg)
h_f	Flow Inducing Differential Pressure (kg/ m^2)
H_{G-F}	Gas Purifier Fuel Oil Heat Input (MJ/ ℓ)
H_{K-F}	Kiln Fuel Oil Heat Input (MJ/ ℓ)
h_v	Enthalpy of Water Vapor Referenced to 273°K (MJ/kg)
h_y	Enthalpy of Gas Constituent y Referenced to 273°K (MJ/kg)
I_ℓ	Line Current (amps)
k	Thermal Conductivity of Air $\frac{(BTU}{ft^2 min^\circ R}$ or $\frac{MJ}{m^2 min^\circ K}$)
L	Duct Length or Surface Length (m)
M_{AX}	Mass Flow Rate of Dry Air at Fan X Inlet (kg/min)
M_{aX}	Air Mixture Flow Rate (kg/min)
M_K	Raw Kiln Crossover Duct Mass Flow Calculation (kg/min)
M_{KL}	Corrected Kiln Crossover Duct Mass Flow (kg/min)
M_P	Raw Gas Purifier Discharge Mass Flow Calculations (kg/min)
M_{PC}	Corrected Gas Purifier Discharge Mass Flow Calculation (kg/min)
M_R	Refuse Feed Rate (mg/hr)
M_r	Residue Mass Flow Rate (kg/min)
M_{vs}	Mass Flow Rate of Vent Steam (kg/min)
M_w	Molecular Weight (kg/kg-mole)
M_w	Mass Flow Rate of Vaporized Water in Quench Pit (kg/min)

M	Mass Flow Rate of Moisture at Fan X Inlet (kg/min)
M _{wx}	Mass Flow Rate of Gas Constituent Y Referenced at 273° (MJ/kg)
M _y	Steam Flow To Kiln Burners #1 & #2 (kg/min)
M ¹⁻²	Steam Flow To Gas Purifier Burners #7 & #8 (kg/min)
N ⁷⁻⁸	Nusselt Number
P ^u	Power (kw)
P	Air Ambient Density (kg/m ³)
P ^a	Barometric Pressure (kg/m ²)
P ^B	Power Factor
P ^E	Prandtl Number
Q	Volume Flow Rate (m ³ /min)
q _{AX}	Sensible Heat of Dry Air at Fan X Inlet (MJ/min)
q _C	Convective Heat Transfer Rate (MJ/min)
q _{dL}	Boiler/Economizer Discharge Duct Heat Loss (MJ/min)
q _{GP-S}	Gas Purifier Burner Steam Heat Input (MJ/min)
q _{K-S}	Kiln Burner Steam Heat Input (MJ/min)
q _{P-L}	Gas Purifier Heat Loss (MJ/min)
q _{P-V}	Quench Pit Vaporized Water Sensible Heat (MJ/min)
q _R	Heat Transferred by Radiation (MJ/min)
q _r	Sensible Heat In Residue (MJ/min)
q _{R-C}	Lost Heat of Combustion in Residue Char (MJ/min)
q _S	Sensible Heat in Slag (MJ/min)
q _{SP}	Sensible Heat in Kiln Spillage (MJ/min)
q _{WX}	Sensible Heat of Dry Air at Fan X Inlet (MJ/min)
q _{XL}	Kiln Heat Loss Rate (MJ/min)
q _Y	Sensible Heat Flow Rate of Gas Constituent Y (MJ/min)
R	Gas Constant (kg-m/kg°K)
R _{CI}	Duct Internal Convective Heat Resistance
R _{CO}	Duct External Convective Heat Resistance
Re	Reynolds Number
R _K	Conductive Heat Resistance
Sp. ht.	Specific Heat (MJ/kg°K)
T	Temperature (°K)
t	Material Thickness
T	Ambient Temperature (°K or °R)
T ^a	Corrected Temperature (°K)
T ^c	Gas Purifier Gas Temperature (°K)
T _{GP}	Internal Bulk Temperature (°K)
T _I	Indicated Facility Temperature (°K)
T _i	Surface Temperature (°K or °R)
T _s	Reference Temperature (°K)
U ⁱ	Overall Heat Transfer Coefficient
V	Gas Velocity (m/sec)
v	Specific Volume of Steam (m ³ /kg)
V _K	Kiln Overall Heat Transfer Coefficient (MJ/min m°K)
V _{AX}	Air Velocity at Fan X Inlet (m/min)
ω	Humidity Ratio
ΔT	Temperature Differential (°K)
μ	Absolute Viscosity (kg/m-sec)
ν	Kinematic Viscosity (m ² /sec)
ρ	Material Density (KG/M ³)
ρ _{VS}	Density of Vent Steam (KG/M ³)
σ	Steffan-Boltzman Constant 1.714 x 10 ⁻⁹ (BTU/hr ft ² °R ⁴)

ACKNOWLEDGMENT

This evaluation program was performed under EPA Contract No. 68-01-4359, "Technical and Economic Evaluation of the EPA Demonstration Resource Recovery Project in Baltimore, Maryland."

The EPA Project Officer was Mr. David B. Sussman of the Office of Solid Waste, Washington, D.C.

Testing was carried out at the demonstration facility in Baltimore, Maryland with the cooperation of the City plant staff and the Monsanto on-site engineering staff. The contribution of both of these groups has been greatly appreciated. The contribution of Dr. H. G. Rigo and Richard Eckels, along with other staff members, is also acknowledged.

Systems Technology Corporation would like to express its gratitude to the above named individuals and all others associated with this evaluation.

APPENDIX A

KILN MODEL DESCRIPTION

INTRODUCTION

The heart of the Landgard Waste Disposal Process is the rotating kiln. The processing of waste within the kiln is an exceedingly complicated process with many phase changes, combustion and complicated chemical reactions taking place in different portions of the kiln. Specific areas in which these take place and the speed and efficiency with which they occur are all important aspects of the operation of the kiln and have a direct bearing on the controllable operating parameters of the kiln.

Because of the inability to physically vary many of the parameters affecting the operation of the kiln at Baltimore, it was decided to develop a mathematical simulation model of the processing kiln. The model was designed to be flexible enough to permit parametric changes of values in the mathematical equations. This would enable the use of the model to predict kiln performance at various scale factors and modes of operation. The ability of the model to accurately simulate the actual operation of the kiln was assessed by entering field measured inputs and comparing the computed outputs to field measured outputs.

DEVELOPMENT OF THE MODEL

A common approach to mathematical simulation of any complicated process is to begin with the complex process and make simplifications to achieve a workable level of realistic engineering relationships. Stepwise sophistication is then added to this simplified version until the mathematical simulation adequately describes the real life situation. What is adequate in any particular case depends upon the level of sophistication desired on the part of the evaluator.

Kiln Process

The kiln process has been discussed previously but will be summarized again. The major inputs and outputs of the kiln are: refuse entering the kiln at the feed end and residue exiting the kiln at the discharge end, air and fuel oil entering the discharge end, the kiln off gases exiting the feed end, and surface heat loss. Some other minor inputs include fuel oil from the safety burners at the feed end, burner atomizing steam at both ends, vaporized water from the seal tanks at both ends, and leakage air through the kiln seals at each end and through the ram tubes at the feed end.

As the shredded refuse tumbles down the kiln, it undergoes thermal processing in three stages where the temperatures progressively increase. The three stages are drying, pyrolysis, and combustion. In the drying process, an endothermic reaction, the heat is supplied by hot gases formed in the combustion stage. In the pyrolysis process, also an endothermic reaction with the heat similarly supplied by the hot gases from the combustion stage but at a higher temperature, the refuse is decomposed into combustible gases such as CO, H₂, CH₄, and other hydrocarbons. In the combustion process, an exothermic reaction, carbon char and pyrolytic gases are combusted to provide the heat for the endothermic drying and pyrolysis reactions making the entire processing sequence self-sustaining. The three thermal processes are controlled by limiting the combustion air, supplied by the fans in the kiln feed hood, to a fraction of the stoichiometric requirement. The main method of heat transfer in the kiln is radiation but some convective and conductive heat transfer occurs between the refuse, the gases, and the refractory within the kiln.

Simplification of the Kiln Process

The first simplification was to consider all minor inputs negligible, resulting in a simplified flow diagram (Figure A-1). This is a valid assumption, since these flows are only a small percentage of the total input flow. The kiln process can be further simplified by considering it to be two separate streams flowing in opposite directions with mass and energy transfer between these two streams. Because the kiln is rotating horizontally, the flow pattern of the two streams are theoretically helical (Figure A-2). This flow pattern, which is extremely complicated and difficult to model, was simplified by assuming the mass flow of the solid material is maintained in the lower segment of the kiln while the mass flow of gases is maintained in the upper segment of the kiln. Therefore, the analytical procedure presumes plug flow of the mass through the kiln.

Convection from the gas flow, radiation, and conduction from the kiln wall transfer heat to the solid mass tumbling through the kiln. This heat provides the energy required for the drying, pyrolysis and vaporization occurring in the lower segment.

It was resolved that the mathematical simulation should provide mass as well as energy balance capability. A search of the literature for acceptable formulations disclosed a publication which treated the energy balance within a furnace chamber by predicting the effect of allowance for radiation exchange on the distribution of temperature and heat transfer*. This technique did not provide for mass balance; nor did any reference appear in the literature where both energy and mass balances had been simultaneously treated. Other problems associated with the use of the Hottel-Cohen technique to simulate the kiln were that their combustion chamber was fixed rather than rotational and their fuel was coal as opposed to highly variable, heterogeneous solid waste. It was, therefore, decided to modify this technique and to extend it to calculate mass as well as energy balances.

*Hottel, H. C., and E. S. Cohen. Radiant Heat Exchange in a Gas Filled Enclosure: Allowance for Nonuniformity of Gas Temperature. A.I.C.E. Journal 4 (11): 3-14, 1958.

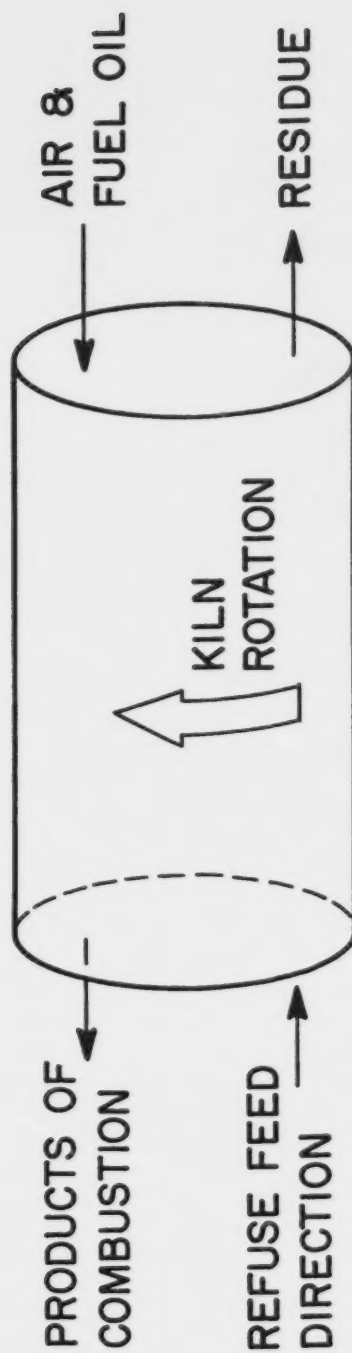


Figure A-1. Simplified kiln flow diagram.

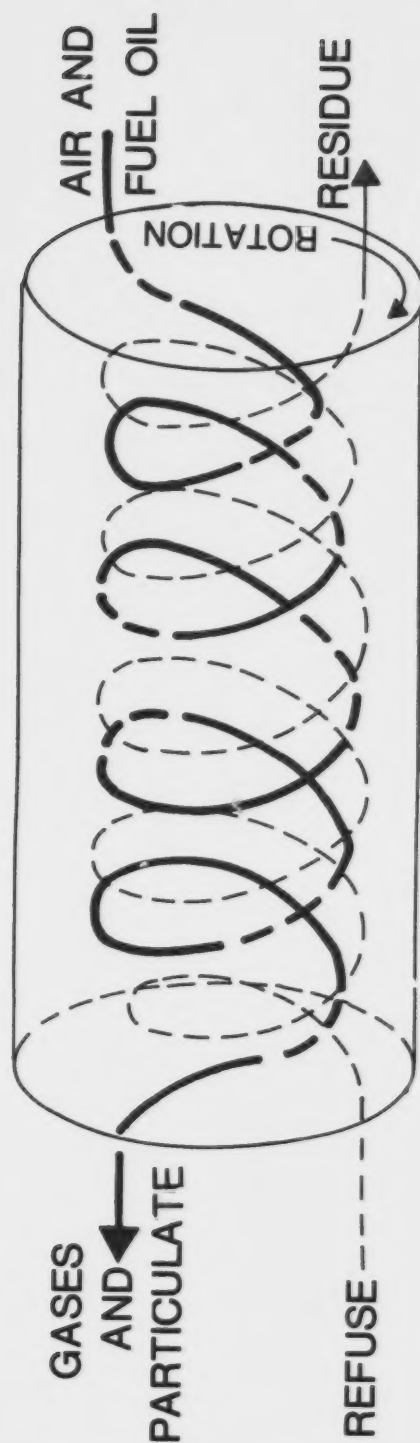


Figure A-2. Mass flow relative to the rotating kiln.

Since this technique used the finite element approach, the kiln model was further simplified by approximating the actual cylindrical kiln as a rectangular box with approximately the same dimensions as the actual kiln. To approximate the two streams, the box was divided horizontally to represent conditions along the length of the kiln and the box was divided vertically into various finite elements (Figure A-3). The dimension of the element was a function of the rotational speed of the kiln, the feed rate of refuse, the density of the refuse, and the number of elements selected for analysis. The resulting length of the imaginary element is, therefore, not simply an integral portion of the true kiln length but is representative of retention time of mass in each imaginary element.

The retention time is dependent upon how many points are selected to represent the length of the kiln. The number of points selected is the number of finite elements to be used in the analysis. The elements are considered to be cubic, having a side dimension based upon the retention time given by the equation:

$$B = \frac{L}{nV} \sqrt[4]{\frac{V^2 + \omega^2 D^2}{2 \frac{\pi}{60}}}^{0.5}$$

where

- L = Length of kiln in feet
- n = Number of analytical elements
- V = Velocity of incoming refuse (feed stock) in feet per second
- D = The diameter of the kiln in feet
- ω = Angular velocity of the kiln in RPM's
- B = Side dimension of each element

Finite Element Analysis

The final simplification is to analyze each finite element using the principles of conservation of mass and energy. The assumptions used in applying these principles for both the lower and upper elements are discussed below.

Lower Elements--

The only allowable processes occurring in the lower elements, which contain the solid waste, are evaporation, pyrolysis, and volatilization of fixed carbon. Each produces a mass transfer to the element immediately above the element losing the mass (Figure A-4). This assumption provides a tractable model, and is quite realistic. Each of the three processes is a function of the temperature within the element.

The evaporation of moisture from the refuse into the upper element directly above is defined in the model as a linear function of the temperature of the lower element as well as the temperature of the upper element*. In

*Perry, R. H., and C. H. Chilton. Chemical Engineers' Handbook. McGraw-Hill, New York, New York 1973.

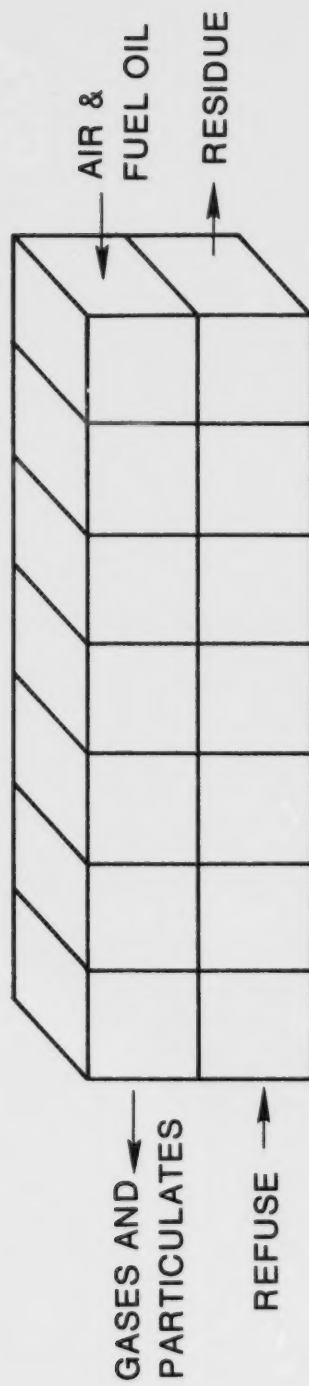


Figure A-3. Model of mass flow through the kiln.

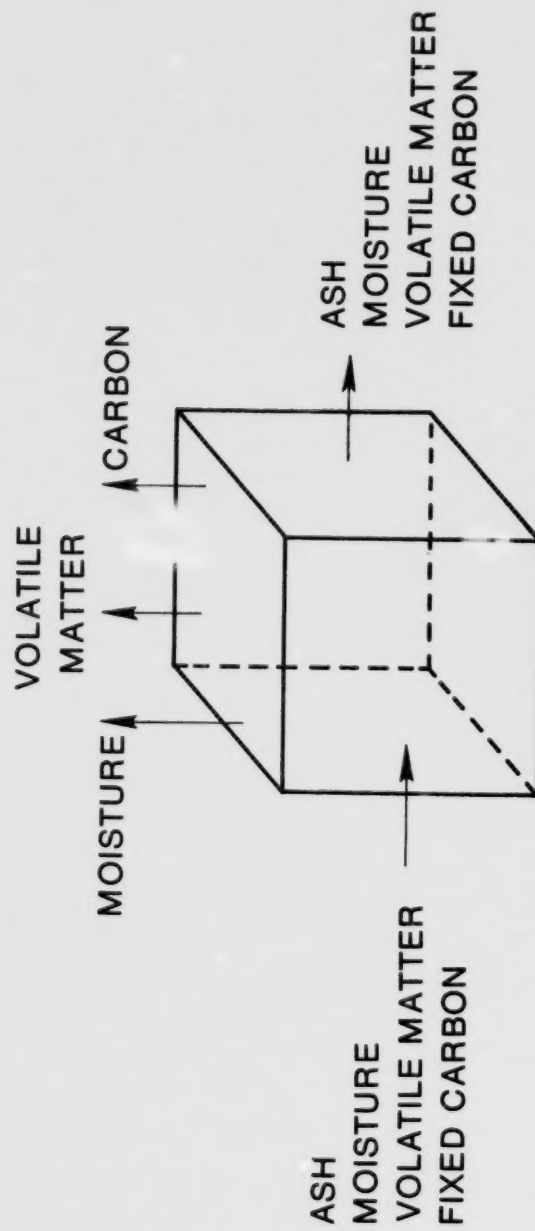


Figure A-4. Mass fluxes through lower elements.

order to simulate reality to the highest possible degree, the pyrolytic process was patterned after published data for the pyrolysis of the lignite fuel*. The volatile material is approximated as pure cellulose ($C_6H_{10}O_5$) and is pyrolyzed at a rate that varies exponentially with time and linearly with temperature:

$$m_{vm} = f(\text{Temperature}) \exp(\text{Time})$$

The products of pyrolysis are carbon, hydrogen, oxygen, methane, ethane, and volatile matter. The "volatile matter" is a collective term that is allowed to include all products with molecular weights higher than ethane, including vaporized cellulose.

The volatilization of carbon from the fixed carbon state in the lower elements to the dissociated state in the upper elements is defined in the model as a linear function of the temperature of the lower element:

$$m_c = f(\text{Temperature})$$

The conservation of mass is applied to each element in order to predict the percentages of each component in each element. The upper elements are in every case the receptors of mass from the physical changes in the lower elements. These mass transfers include evaporated water, volatile matter, and volatilized carbon.

The energy transfers to and from a lower element are illustrated in Figure A-5. The energy of the solids entering a lower element is defined as the enthalpies of the various components (moisture, volatile matter, fixed carbon, ash) using the temperature of the previous element. In a similar manner the energy of the solids exiting the element can be determined using the temperature of the element. The energy of the mass lost to the upper element is similarly determined using the temperature of the element and the heats of vaporization†. Radiative heat transfer occurs between all elements and the kiln wall while conductive heat transfer occurs with the kiln wall.

Upper Elements--

The upper elements, which contain air, vaporized solids, and the products of combustion, are the receptors of the evaporated water, volatilized carbon and pyrolytic products. By definition combustion is allowed to occur only in the upper elements. The combustibles are fuel oil, carbon, and volatile matter (pyrolytic products), (Figure A-6). It was assumed that fuel oil behaves as methane and that products of combustion consist of carbon dioxide,

*Lowery, H. H. Chemistry of Coal Utilization. John Wiley and Sons, Inc., New York, New York, 1963.

†Perry, R. H., and C. H. Chilton. Chemical Engineers' Handbook. McGraw-Hill, New York, New York, 1973.

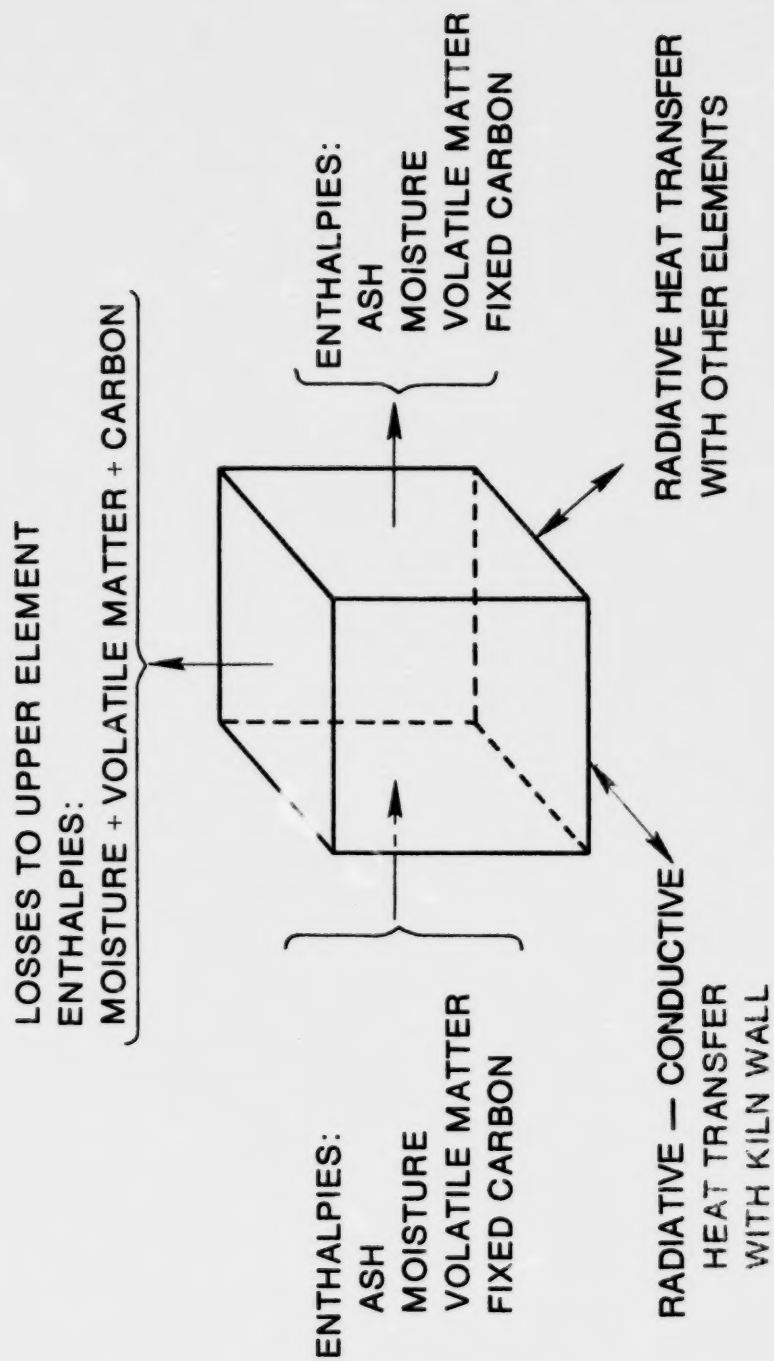


Figure A-5. Energy fluxes in the lower elements.

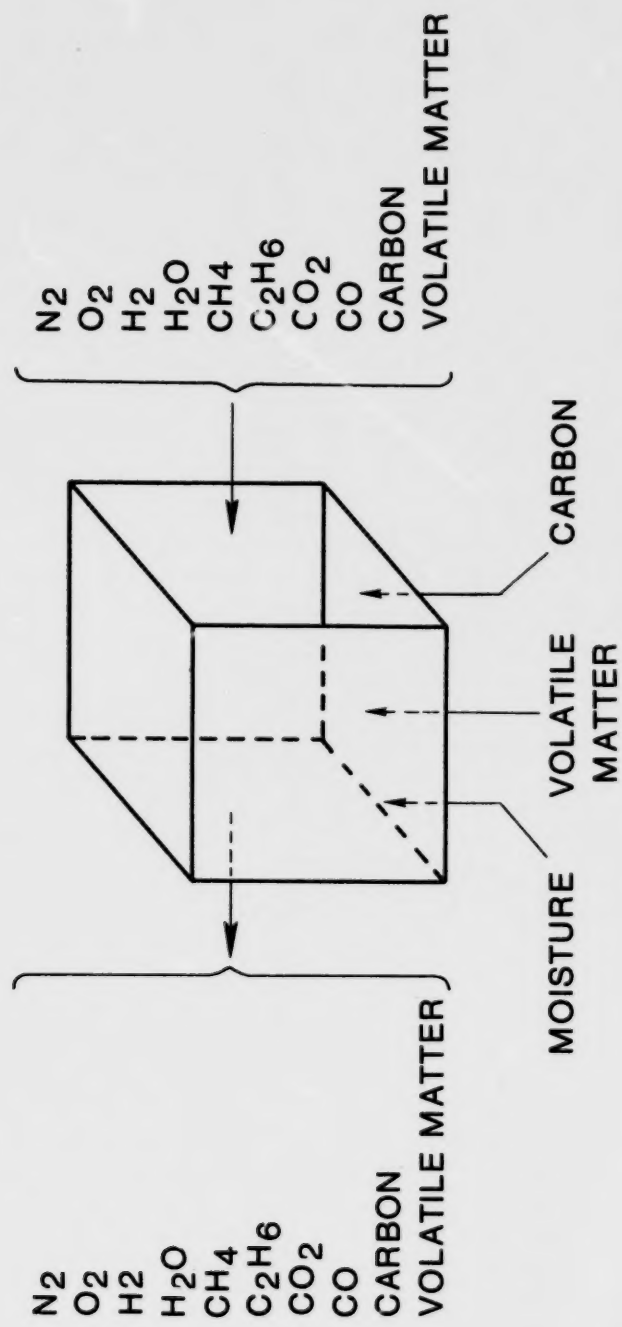


Figure A-6. Mass fluxes through upper elements.

water, carbon monoxide, and hydrogen*. The fixed carbon is considered to oxidize in a manner that results in products consisting of carbon dioxide, carbon monoxide, and fixed carbon. For purposes of computation all unidentified volatile matter, which is assumed to be cellulose ($C_6H_{10}O_5$), is allowed to react in the presence of available oxygen, to yield carbon monoxide, carbon dioxide, carbon, hydrogen, methane, ethane, water, and uncombusted cellulose.

The vaporization of fixed carbon, and the total pyrolysis of cellulose from the lower element directly below into an oxygen-starved atmosphere of the upper element contribute to the carbon content of the upper region. The carbon and fly ash, in the kiln coagulate to form a particulate component in the otherwise gaseous discharge. The kiln model disregards the fly ash, and treats the particulate as free carbon.

Carbon dioxide is formed from the volatilized carbon whenever oxygen is available. The carbon contends with the free hydrogen for the available oxygen. Simultaneous solution of model balance equations for carbon, hydrogen and oxygen are used to predict the amounts of each respective species.

The energy fluxes in the upper elements are illustrated in Figure A-7. The energy of the inlet gases was determined by summing the individual enthalpies of the various component gases at the temperature of the previous element. The energy of the outlet gases is determined in a similar manner using the temperature of the element. The energy input due to the mass gain from the lower elements is equal to the value obtained in the lower elements analysis.

Any energy release in an upper element due to combustion is added to that element. Radiative and convective heat transfer occurs with the kiln wall. Radiative heat transfer occurs with all other elements and is temperature dependent.

Conservation of Mass--

The conservation of mass principle is applied as mass is transferred from element to element due to physical and chemical changes and the normal flow pattern. As shown in Figure A-8, mass is introduced into the kiln model at two locations. Solid refuse enters the first lower element (1) while air and fuel oil are introduced in the upper element at the opposite end (n). The flow of gases in the upper elements is initialized by the air and the fuel oil injected into the kiln and is combusted to completion in the nth element with very little, if any, oxygen remaining. As the gas stream flows from element to element its mass is increased by the mass lost in the lower elements due to the thermal processes of evaporation and volatilization. Therefore, as the refuse flows from element to element its mass correspondingly decreases. Combustion of the vaporized/volatilized material in an upper element does not effect the total mass in an element, but does change the mass of the specific species, so each chemical reaction results in the conversion of mass from the previous to the present chemical species.

*American Society of Mechanical Engineers. Combustion Fundamentals for Waste Incineration. New York, New York, 1974.

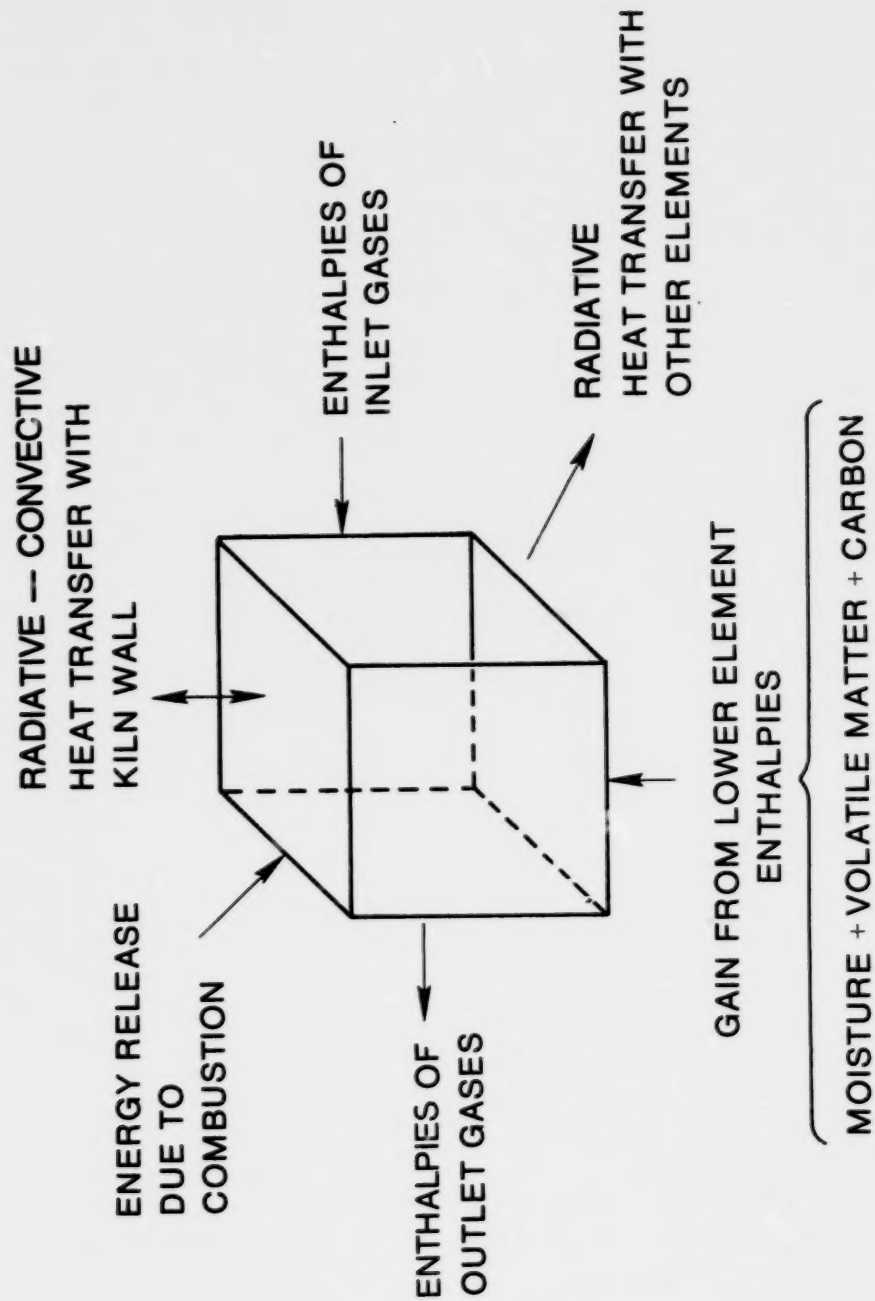


Figure A-7. Energy fluxes in the upper elements.

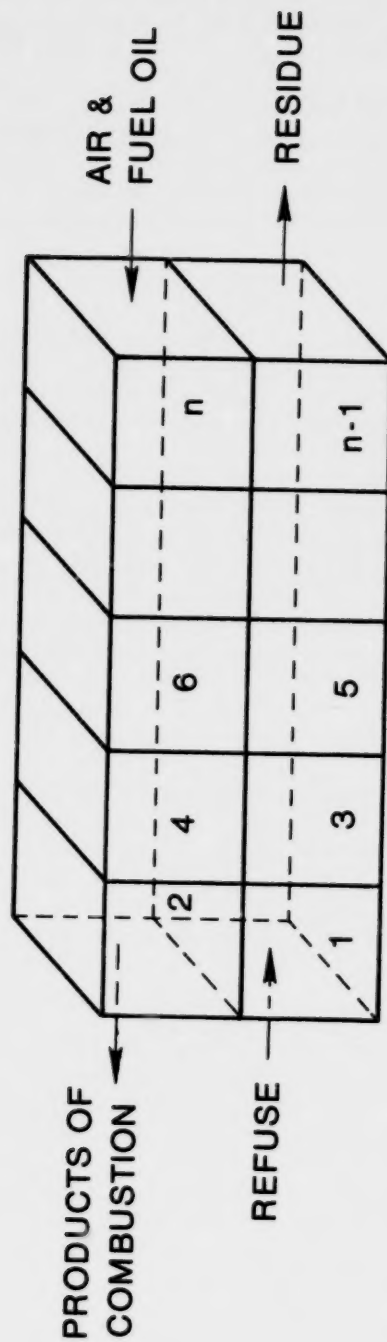


Figure A-8. Finite element numbering scheme.

Since the mass transfer rates can be defined as functions of the temperature, it is possible to calculate the mass flow into and out of each element, for a given temperature. Thus, the conservation of mass through the kiln is effected element by element, resulting in the calculated percentage of each material component in each element.

By performing the appropriate calculation to conserve mass in each of the lower elements as the refuse progresses to its ultimate discharge, the analysis of the residue can be determined. In the same manner, by tracking the mass into and out of each of the upper elements and considering the chemical reactions involved in each element, the composition of the outlet gas can be defined.

Conservation of Energy--

The conservation of energy principle is used to verify or negate the temperature assumptions used for the conservation of mass. An average temperature for each element is calculated considering the temperature of its neighbors, and an average energy flux due to radiation is derived from this temperature.

The heat transfer due to radiation is the dominant energy transfer mechanism in the balance. Consequently, the element temperatures are the basis for the calculations of energy transfer into and out of each element. The net radiation is algebraically added to the energy gained from net mass transfers into the element and to energy released by chemical reactions occurring within the element. The inside temperature of the kiln wall is calculated using the element temperatures, and from the resultant value, the convective energy transfer between the lower and the upper elements is calculated.

By summing all energies entering and generated in each element and subtracting the energies leaving the element, the imbalance can be used to adjust the temperature for that element. By performing a sufficient number of iterations for the entire set of elements, the imbalance can be reduced to any non-zero value desired. Thus, the temperature profile can be determined to the desired accuracy by using a computer iteration technique.

COMPUTER PROGRAM

A fortran program was written to permit rapid, repetitive numerical analyses based on this mathematical model, while providing the opportunity to selectively alter parameters of the kiln design and/or operation to study the impact of the changes on kiln temperature and reaction products.

The flow diagram for the computer program is shown in Figure A-9. The inputs required for the program and their symbols are as follows:

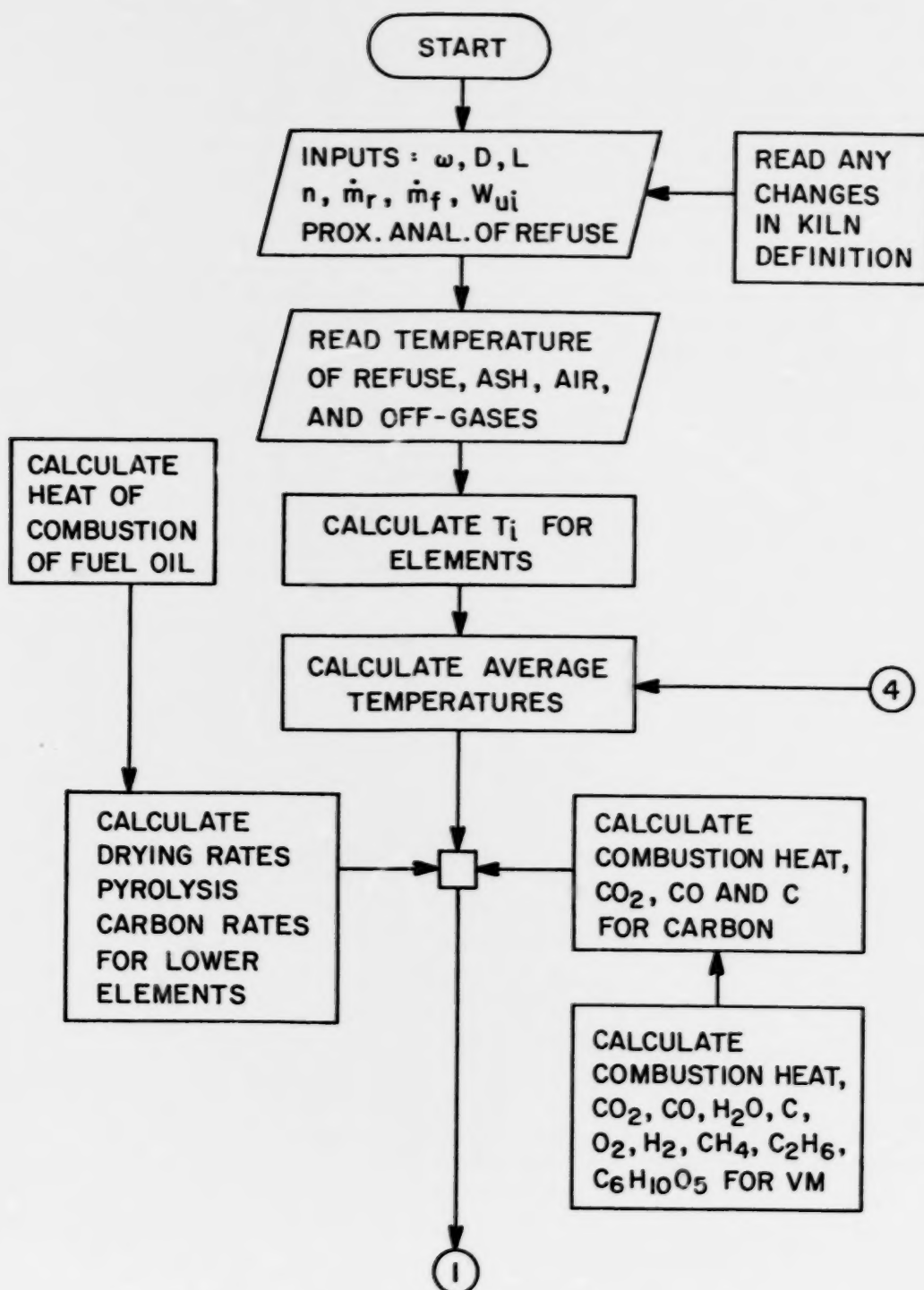


Figure A-9. Computer program flow diagram. (Continued)

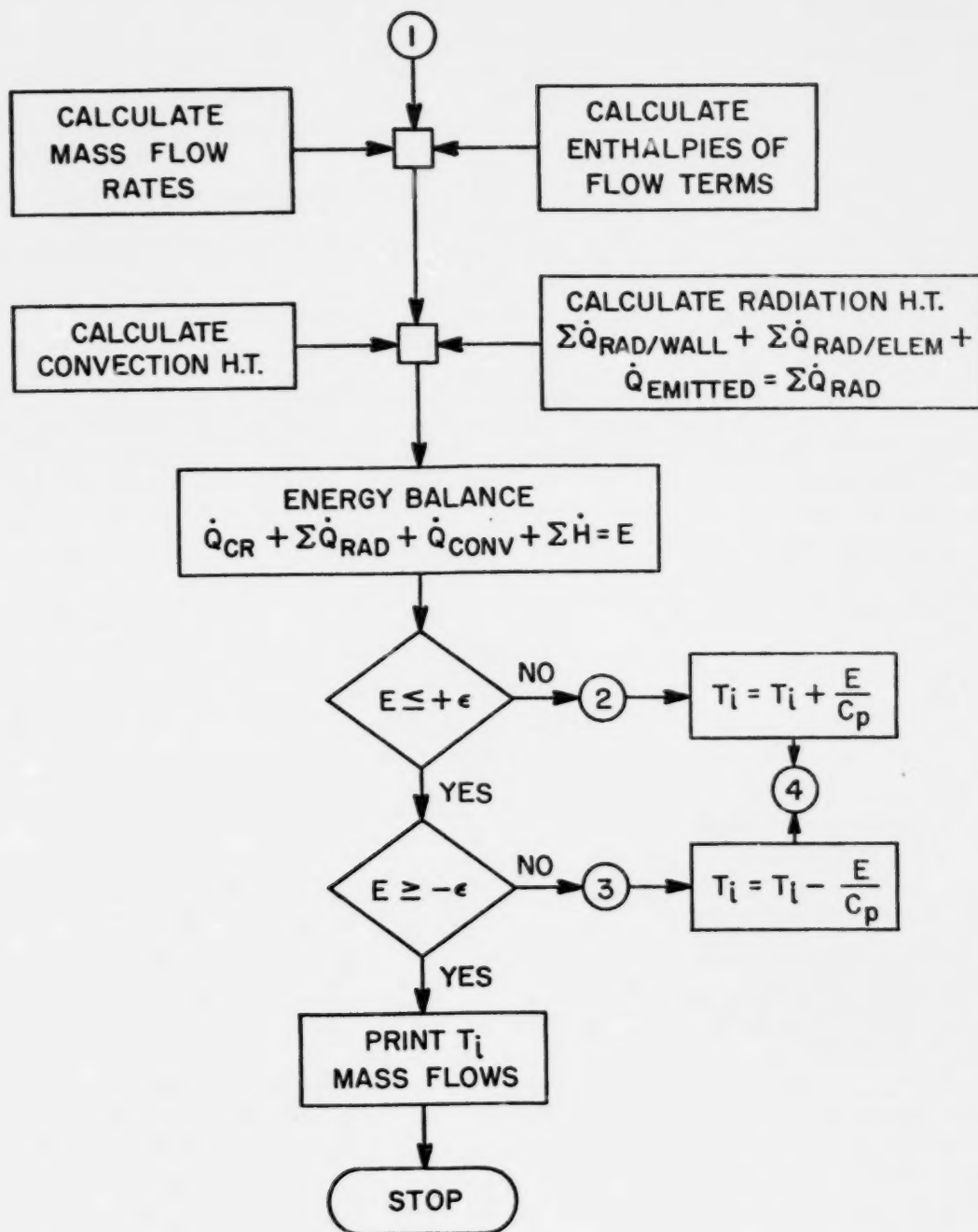


Figure A-9. (Concluded)

<u>Input</u>	<u>Symbol</u>
rotational speed	ω
kiln diameter	D
kiln length	L
number of elements	n
refuse mass rate	$\dot{m}_r$
fuel oil mass rate	$\dot{m}_f$
air mass rate	$\dot{m}_a$
ambient air relative humidity	
outside kiln wall temperature	
proximate analysis of the refuse	
approximate temperature of element at each in/out port of kiln	

Each of these values, except the last four temperature approximations, affect the results of the model outputs and may be varied in order to study their effects on the kiln operation. In addition to the operational variables that would influence the operation of a defined kiln, the kiln itself may be redefined as to its length, diameter, rotational speed, wall thickness, and thermal properties.

To reduce the number of iterations the approximate temperatures at the refuse inlet, the air and fuel oil inlet, the residue outlet, and the off gas outlet are read into the program. Using this data the program generates two linear temperature profiles, for the upper and lower elements based upon the four assumed temperatures. These temperatures (T^*), at the interface of element, are averaged to obtain an internal element temperature. The program then subjects the data to a finite element analysis constrained by conservation of mass and energy. The energy imbalance of each element (E) is compared to a predetermined value the temperature approximations are incrementally adjusted to correct the discrepancy and another iteration is performed with the new temperatures.

If the net energy contained within an element is correct within the predetermined limits that element is in balance. When this conservation of energy criterium has been met for each element the program has reached completion and the Temperature Profile and Chemical Analyses are printed. The degree of accuracy obtained is, therefore, controlled by the limit of allowable error in the temperature profile, and the number of elements used for the analysis.

The outputs of the program are temperature profiles for each of the upper and lower regions of the kiln, and chemical analyses of the outlet gasses, entrained particulates, and the solid residue. The foregoing discussion has shown how these outputs are mathematically attained and how they are dependent upon certain user supplied starting conditions.

While this model was specifically designed after the Baltimore system, it is flexible enough to realistically analyze and predict the performance of rotary kilns of other types and configurations. A listing of the computer program is provided as Appendix D.

APPENDIX B

MASS AND ENERGY BALANCE

SECTION B-1

INTRODUCTION

This appendix presents the data acquisition techniques, stream characterizations, and the mass and energy balances in more detail than Volume II. Also included are the methods of calculating the balances.

All general plant stream characterizations such as electricity, water and sewer will be included at the beginning of this section. The receiving, size reduction, and storage and recovery modules will then be discussed together as the waste preparation subsystem. The next section will be a detailed discussion of the thermal processing and energy recovery modules. Besides the detailed stream characterizations and detailed sampling techniques, the numerous balances generated from SYSTECH and Monsanto data will be presented. The final section will contain data acquisition techniques and stream characterization data for the residue separation module and the gas scrubber system.

The information is presented to explain sampling techniques employed in this study, and to present the necessary data for those who wish to examine the process in more detail.

As mentioned previously in Volume II, much of the data was collected by Monsanto, the City of Baltimore, TRW, and Environmental Elements Corporation.

SECTION B-2

GENERAL PLANT

ELECTRICAL POWER DEMAND

The total plant power demand for the three levels of operation (downtime, standby, and operating) was determined from a computer printout supplied by Baltimore Gas and Electric Company. The computer printout gave a 15 minute average of the power demand. Using the operational status during the period, Table B-1 was generated.

The electrical energy demand for each module was measured in order to allocate the cost of electricity to each module, and for use in the unit process and subsystem balances. The module electric power demand was calculated by summing the electric power demand of the major pieces of equipment and facilities that comprise the module. The line current for each piece of equipment was measured at the power box in the motor control center by using a recording clamp-on, split core ammeter. The electrical power demand (P) was then calculated using the measured line current (I_ℓ), the known line voltage (E_ℓ), and estimated power factor (P_f), and the following equation:

$$P = 3 E_\ell I_\ell P_f$$

The power factor was estimated based upon the specific facility or equipment being considered. Building power factors were estimated between 0.95 and 1.00 because lights and heating elements have a power factor of 1.0 while the small motors (0 - 5 hp) within the building circuit have a power factor of 0.8 to 0.95. The larger motors were estimated to have power factors of 0.5 to 0.8 with the largest motors having the smallest power factor. The electric power demand for the individual modules is shown in Tables B-2 through B-8.

WATER CONSUMPTION

The plant water consumption was determined by daily readings of the main plant water meter. This data, shown in Table B-9, was collected both during periods when the scrubber was off and during periods when it was on. Similarly measurements were made both when the gas purifier was water cooled and when it wasn't. This data was collected during periods when the plant was operating at different throughput rates.

The supply water composition measured by the City is compared to the grab sample analyses performed by SYSTECH in Table B-10. The water generally has low concentrations of most of the commonly measured parameters that indicate a water of high quality. However, with a hardness of approximately 75 mg/l the water does require softening before use in the boilers.

TABLE B-1. TOTAL PLANT ELECTRICAL ENERGY DEMAND*

<u>Downtime</u>		
Date		Average Demand (kw)
4/14/77		165
4/15/77		138
4/16/77		135
4/17/77		124
4/18/77		150
Average		142
<u>Standby</u>		
Date		Average Demand (kw)
5/01/77		1,230
5/02/77		980
5/08/77		1,118
Average		1,109
<u>Operating</u>		
Date	Hours Operating	Average Demand (kw)
4/26/77	22.3	1,768
4/27/77	23.3	1,744
4/28/77	22.2	1,796
4/29/77	22.8	1,794
5/04/77	21.8	1,782
5/05/77	21.3	1,695
5/06/77	23.5	1,849
5/10/77	23.5	1,926
5/11/77	22.5	1,753
5/12/77	23.0	1,857
5/13/77	23.0	1,808
Average	22.7	1,797

*Data supplied by Baltimore Gas and Electric Company.

TABLE B-2. RECEIVING MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Receiving building	16.6	440	39	39	39	
Sump pump	Int.	440	0	0	0	
Total			39	39	39	

TABLE B-3. SIZE REDUCTION MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Storage pit conveyor	4.9	440	3.0	3.0		
Storage pit conveyor	4.8	440	3.0			
Shredder feed conveyor	8.25	440	5.3	5.1		
Shredder feed conveyor	7.70	440	5.1			
Shredder (new hammers)	58.9	4160	382.0	382.0		
Shredder (idle)	42.0	4160	272.0			
Shredder discharge conveyor	12.8	440	8.2	8.6		
Shredder discharge conveyor	14.25	440	9.2			
Shredder building	16.6	440	10.7	10.7	10.7	10.7
Total				409.3	10.7	10.7

TABLE B-4. STORAGE AND RECOVERY MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Shredded refuse collection conveyor	10.3	440	6.8	6.8		
Shredded refuse elevating conveyor	13.4	440	8.9	8.9		
Shredded refuse transfer conveyor	10.7	440	7.0			
Storage and recovery unit	64.7	440	43.4			
Storage and recovery unit outfeed conveyor	11.4	440	7.4			
Stored material spreader	2.0	440	1.2			
Transfer tower	18.6	440	12.4	12.4	12.4	12.4
Total			28.0	28.0	12.4	12.4

TABLE B-5. THERMAL PROCESSING MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Kiln feed conveyor	6.15	440	4.0	4.0	--	--
Ram feeders	39.55	440	26.2	26.2	--	--
Ram feeders	34.9	440	23.1	23.1	--	--
Kiln drive	55.5	440	36.8	36.8	36.8	--
Refuse combustion air fan	11.4	440	7.6	7.6	7.6	--
Kiln combustion air fan	21.3	440	13.9	13.9	13.9	--
Gas purifier combustion air fan	--	440	--	--	7.5	--
Combustion fan	--	440	--	--	--	--
Dust collection fan	55.5	440	36.4	36.4	36.4	--
Induced draft fan	135	4160	875.4	875.4	875.4	--
Scrubber pump	52	4160	337.2	--	--	--
Sludge pump	2.4	440	1.4	--	--	--
Dehumidifier fan	22.0	440	14.1	14.1	14.1	--
Dehumidifier fan	19.5	440	12.5	12.5	12.5	--
Dehumidifier fan	22.2	440	14.2	14.2	14.2	--
Dehumidifier fan	18.6	440	11.9	11.9	11.9	--
Dehumidifier fan	22.0	440	14.1	14.1	14.1	--
Dehumidifier fan	22.0	440	14.1	14.1	14.1	--
Clarifier	1.35	440	0.8	--	--	--
Spillback screw conveyor	3.6	440	2.2	2.2	2.2	--
Slag screw conveyor	3.6	440	2.2	2.2	2.2	--
Transfer screw conveyor	4.5	440	2.8	2.8	2.8	--
Residue quench tank conveyor	14.0	440	8.9	8.9	8.9	--
CO ₂ analyzer	3.0	440	1.9	1.9	1.9	--
Fuel oil pump	15.0	440	10.2	10.2	102.0*	--
Total			1,132.5	1,132.5	1,178.5	--

* Estimated

TABLE B-6. RESIDUE SEPARATION MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operation (kw)	Standby (kw)	Downtime (kw)
Separation screen conveyor	2.11	440	1.3	1.3	1.3	--
Residue building	9.45	440	6.8	6.8	6.8	6.8
Glassy aggregate screen conveyor	2.7	440	1.7	1.7	1.7	--
Glassy aggregate stacker conveyor	3.15	440	2.0	2.0	2.0	--
Residue flotation unit	1.5	440	0.9	0.9	0.9	--
Sinks discharge conveyor	1.2	440	0.7	0.7	0.7	--
Total			13.5	13.5	13.5	6.8

TABLE B-7. ENERGY MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Jag valve	1.2	440	0.7	--	--	--
Feed water pump	153	440	104.9	--	--	--
Degasifier pump	13.2	440	8.7	8.7	8.7	--
Water treatment building	19.5	440	14.2	14.2	14.2	14.2
Water treatment heater	25.2	440	19.2	19.2	19.2	19.2
Total				42.1	42.1	33.4

TABLE B-8. GENERAL PLANT MODULE ELECTRIC POWER DEMAND

Description	Current (amperes)	Voltage (volts)	Power (kw)	Operating (kw)	Standby (kw)	Downtime (kw)
Office building	9.3	440	7.1	3.6	3.6	3.6
Control panel	3.15	440	2.4	2.4	2.4	2.4
Uninterruptable power	9.7	440	7.0	7.0	7.0	7.0
Service building	10.0	440	7.2	7.2	7.2	7.2
Street lights	16.2	440	12.3	6.1	6.1	6.1
Heat tracing	2.7	440	2.1	2.1	2.1	2.1
Air compressor	21.9	440	14.2	14.2	14.2	
Maintenance	33.0	440	24.0	15.9	15.9	15.9
Cooling water pump	3.9	440	2.4	2.4	2.4	2.4
Cooling water pump	10.6	440	6.5	6.5	6.5	6.5
Wastewater lift station	9.6	440	6.1	2.0	2.0	1.0
Total				69.4	69.4	54.2

TABLE B-9. WATER CONSUMPTION

Date	Liters/Day	Date	Liters/Day
11/15/76	2,188,866	1/18/77	1,958,799
11/16/76	2,594,803	1/19/77	1,956,542
12/07/76	1,356,923	1/20/77	2,744,038
12/10/76	1,836,187	1/23/77	2,107,106
12/11/76	1,727,160	1/24/77	2,345,349
12/12/76	2,347,105	1/31/77	2,899,696
12/13/76	2,345,504	2/01/77	2,429,122
12/14/76	2,345,504	2/03/77	3,175,055
12/15/76	2,325,277	2/04/77	2,627,903
12/16/76	1,130,405	2/05/77	2,627,903
12/17/76	2,432,041	2/22/77	1,963,677
12/18/76	2,058,778	2/23/77	2,054,755
12/19/76	2,004,392	2/24/77	2,311,912
12/20/76	2,021,179	2/28/77	2,088,393
01/14/77	2,042,666	3/01/77	2,277,484
01/15/77	1,653,947	3/02/77	1,783,954
01/16/77	1,562,104	3/03/77-3/11/77	1,972,905
01/17/77	1,875,687	3/11/77-3/18/77	1,990,497
Minimum (Liters/Day)		Average (Liters/Day)	
1,130,405		2,084,822	
		Maximum (Liters/Day)	
		3,175,055	

TABLE B-10. ANALYSIS OF CITY WATER

Date		7/75-6/76*	12/1/76	1/31/77	Average
pH		7.7	-	6.4	7.05
Alkalinity	(mg/l)	44.0	60.0	60.0	54.7
Bicarbonates	(mg/l)	53.0	-	-	53.0
Volatile Solids	(mg/l)	36.5	-	-	36.5
Total Solids	(mg/l)	105.3	-	170.0	137.7
Hardness, EDTA	(mg/l)	71.0	81.6	78.0	76.9
Calcium	(mg/l)	20.2	-	-	20.2
Magnesium	(mg/l)	5.4	-	-	5.4
Iron	(mg/l)	0.02	-	-	0.02
Manganese	(mg/l)	0.01	-	-	0.01
Silica	(mg/l)	5.5	-	-	5.5
Aluminum	(mg/l)	0.04	-	-	0.04
Sodium	(mg/l)	5.3	-	-	5.3
Potassium	(mg/l)	1.4	-	-	1.4
Nitrates	(mg/l)	1.2	-	-	1.2
Sulfates	(mg/l)	15.2	-	-	15.2
Chlorides	(mg/l)	14.4	-	18.0	16.2
Fluorides	(mg/l)	0.93	-	-	0.9
BOD ₅	(mg/l)	-	1.0	-	1.0
COD	(mg/l)	-	1.0	-	1.0
TKN	(mg/l)	-	1.0	-	1.0
Total Phosphorous	(mg/l)	-	0.1	-	0.1
Suspended Solids	(mg/l)	-	0.0	-	0.0
Dissolved Solids	(mg/l)	-	70.0	-	70.0

* City of Baltimore, Department of Public Works, Bureau of Operations, Water Division-Purification Section.

WASTEWATER EFFLUENT

The wastewater effluent is pumped by the wastewater lift station to the city sewer system. This wastewater flow was measured by timing the filling cycle of the lift station wet well. The actual flow measurements shown in Table B-11 are directly related to the rate of steam production and therefore the refuse feed rate. The maximum flows occur during manual blowdown of the boilers.

The wastewater is mainly comprised of boilerwater blowdown, process cooling water, and recycled cooling water system blowdown. The method of calculating the respective flows of each of these wastewaters was discussed in Volume II. To briefly recap that discussion the boilerwater constant blowdown rate was determined by comparing the design rate of 10 percent of the boiler feedwater flow to the percentage calculated from the feedwater and boilerwater total solids concentration. The 10 percent rate was confirmed by this method, indicating that the boiler blowdown rate is dependent upon the steam production and therefore the refuse feed rate. The boiler feedwater and blowdown analysis is included in the discussion of the thermal processing subsystem. The manual blowdown rate was estimated from process design data to be 75,600 liters per day independent of the steam production and refuse feed rate. The various cooling water flow rates were determined by measuring the time required to fill a known volume at the discharge of each stream flowing to the sewer. The flow rates of the various cooling waters are as follows:

<u>Water</u>	<u>Flow Rate (lpm)</u>
Shredder bearing cooling water (each)	25.4
Induced draft fan (inboard bearing)	1.9
Induced draft fan (outboard bearing)	1.0

The blowdown and make-up for the recycled cooling water system was estimated from design data to be 75.6 lpm (20 gpm). Based upon the above data and estimated steam rates discussed in the thermal processing section, water and sewer rates were generated for each scenario for use in the economic evaluation (Table B-12).

The composition of the wastewater effluent, which is mainly concentrated city water, was determined by analyzing a composite of grab samples taken over an eight hour period. Often when the grab samples were taken the pH and temperature were measured with the data shown in Table B-13. The effluent is generally hot due to the boiler blowdown, and has a high pH. Chemical analysis of the wastewater revealed that it was low in all parameters measured except for total solids, which are high due to the solids concentration in the boiler blowdown (Table B-14).

TABLE B-11. WASTEWATER EFFLUENT FLOW MEASUREMENTS

DATE	TIME	FLOW (LITERS/MIN.)	DATE	TIME	FLOW (LITERS/MIN.)
2/23/77	1351	166.5	2/25/77	1027	170.7
2/23/77	1358	170.0	2/25/77	1046	174.8
2/23/77	1404	162.3	2/25/77	1050	163.1
2/23/77	1410	163.9	2/25/77	1056	166.5
2/23/77	1417	174.2	2/25/77	1003	165.4
2/23/77	1423	177.2	2/25/77	1108	166.5
2/23/77	1429	180.3	2/25/77	1115	185.1
2/23/77	1435	180.9	2/25/77	1120	152.2
2/23/77	1441	227.1	2/25/77	1127	170.7
2/23/77	1447	178.3	2/28/77	0759	146.9
2/23/77	1453	178.7	2/28/77	0812	143.6
2/23/77	1459	174.8	2/28/77	0819	148.7
2/23/77	1505	178.3	2/28/77	0826	156.2
2/23/77	1510	156.5	2/28/77	0832	158.6
2/23/77	1517	161.3	2/28/77	0839	158.6
2/23/77	1524	162.7	2/28/77	0847	140.7
2/23/77	1530	180.9	2/28/77	0854	141.6
2/23/77	1536	177.2	2/28/77	0901	143.6
2/23/77	1542	175.2	2/28/77	0909	135.9
2/23/77	1549	181.7	2/28/77	0916	136.9
2/23/77	1553	185.1	2/28/77	0923	136.6
2/23/77	1600	185.1	2/28/77	0931	133.2
2/25/77	0816	160.5	2/28/77	0938	136.6
2/25/77	0822	162.3	2/28/77	0942	136.1
2/25/77	0828	159.0	2/28/77	0950	140.7
2/25/77	0834	166.5	2/28/77	0957	138.8
2/25/77	0841	160.5	2/28/77	1005	140.5
2/25/77	0847	162.0	2/28/77	1018	140.5
2/25/77	0856	164.3	2/28/77	1027	137.6
2/25/77	0900	174.2	2/28/77	1034	137.1
2/25/77	0907	168.1	2/28/77	1042	134.7
2/25/77	0912	169.2	2/28/77	1050	123.0
2/25/77	0918	174.2	2/28/77	1059	111.4
2/25/77	0924	178.3	2/28/77	1107	125.8
2/25/77	0930	171.0	2/28/77	1114	137.6
2/25/77	0936	141.9	2/28/77	1121	120.3
2/25/77	0949	168.1	2/28/77	1128	140.7
2/25/77	0955	173.4	2/28/77	1205	142.3
2/25/77	1001	170.7	2/28/77	1211	153.4
2/25/77	1007	173.4	2/28/77	1218	141.6
2/25/77	1013	153.6	2/28/77	1225	138.3
2/25/77	1019	163.9	2/28/77	1223	139.5
2/25/77	1025	165.1	2/28/77	1246	168.9
2/25/77	1031	167.7	2/28/77	1250	276.6

(continued)

TABLE B-11. (Continued)

DATE	TIME	FLOW (LITERS/MIN.)	DATE	TIME	FLOW (LITERS/MIN.)
2/28/77	1256	165.9	3/14/77	1543	297.4
2/28/77	1304	141.6	3/14/77	1545	283.3
2/28/77	1310	140.7	3/14/77	1546	306.1
2/28/77	1317	136.9	3/14/77	1549	295.3
2/28/77	1324	130.1	3/14/77	1550	295.3
2/28/77	1332	118.1	3/14/77	1552	285.2
2/28/77	1341	115.4	3/14/77	1554	295.3
2/28/77	1350	111.1	3/14/77	1556	293.2
2/28/77	1402	115.7	3/14/77	1558	279.5
2/28/77	1407	112.8	3/14/77	1559	260.2
2/28/77	1415	113.8	3/14/77	1601	1040.9
2/28/77	1424	112.2	3/14/77	1602	186.7
2/28/77	1450	113.0	3/14/77	1605	310.7
2/28/77	1459	116.1	3/14/77	1606	185.0
2/28/77	1500	116.1	3/14/77	1609	175.7
2/28/77	1515	112.0	3/14/77	1612	320.3
2/28/77	1523	109.6	3/14/77	1614	289.1
2/28/77	1525	354.4	3/14/77	1615	295.3
2/28/77	1530	248.6	3/14/77	1617	182.7
2/28/77	1536	188.4	3/14/77	1619	287.2
2/28/77	1542	161.1	3/14/77	1621	295.3
2/28/77	1549	188.4	3/14/77	1623	287.2
2/28/77	1554	187.1	3/14/77	1625	287.2
2/28/77	1600	184.2	3/14/77	1626	303.9
2/28/77	1606	181.0	3/14/77	1627	277.6
3/14/77	1509	297.4	3/14/77	1629	295.3
3/14/77	1511	293.2	3/14/77	1631	263.5
3/14/77	1513	287.2	3/14/77	1633	693.9
3/14/77	1514	301.7	3/14/77	1634	189.3
3/14/77	1516	289.1	3/14/77	1636	301.7
3/14/77	1517	240.7	3/14/77	1638	270.4
3/14/77	1522	308.4	3/14/77	1642	293.2
3/14/77	1524	291.2	3/14/77	1644	283.3
3/14/77	1526	293.2	3/14/77	1645	299.6
3/14/77	1528	293.2	3/14/77	1647	277.6
3/14/77	1529	297.4	3/14/77	1649	297.4
3/14/77	1531	293.2	3/14/77	1650	295.3
3/14/77	1533	297.4	3/14/77	1652	297.4
3/14/77	1534	293.2	3/14/77	1654	281.3
3/14/77	1536	295.3	3/14/77	1656	291.2
3/14/77	1538	297.4	3/14/77	1658	308.4
3/14/77	1540	293.2	3/14/77	1700	281.3
3/14/77	1541	291.2	3/14/77	1702	293.2

TABLE B-11. (Continued)

DATE	TIME	FLOW (LITERS/MIN.)	DATE	TIME	FLOW (LITERS/MIN.)
3/14/77	1703	297.4	3/14/77	1825	293.2
3/14/77	1705	260.2	3/14/77	1827	289.1
3/14/77	1706	991.3	3/14/77	1909	194.6
3/14/77	1708	182.7	3/14/77	1910	287.2
3/14/77	1710	308.4	3/14/77	1912	265.2
3/14/77	1711	291.1	3/14/77	1914	289.1
3/14/77	1713	308.4	3/14/77	1915	281.3
3/14/77	1715	275.7	3/14/77	1917	293.2
3/14/77	1716	310.7	3/14/77	1918	297.4
3/14/77	1718	295.3	3/14/77	1920	322.7
3/14/77	1720	301.7	3/14/77	1921	297.4
3/14/77	1721	287.2	3/14/77	1924	265.2
3/14/77	1723	308.4	3/14/77	1924	946.3
3/14/77	1725	289.1	3/14/77	1927	195.0
3/14/77	1727	191.8	3/14/77	1929	315.4
3/14/77	1729	313.1	3/14/77	1931	308.4
3/14/77	1731	187.5	3/14/77	1932	335.8
3/14/77	1733	306.1	3/14/77	1934	297.5
3/14/77	1735	289.0	3/14/77	1936	301.7
3/14/77	1737	299.6	3/14/77	1937	313.1
3/14/77	1739	297.4	3/14/77	1940	297.4
3/14/77	1740	291.2	3/14/77	1941	297.4
3/14/77	1742	301.7	3/14/77	1943	313.1
3/14/77	1744	293.2	3/14/77	1944	310.7
3/14/77	1746	299.6	3/14/77	1946	313.1
3/14/77	1748	297.4	3/14/77	1948	325.3
3/14/77	1749	303.9	3/14/77	1950	320.3
3/14/77	1750	293.2	3/14/77	1952	313.1
3/14/77	1753	297.4	3/14/77	1954	313.1
3/14/77	1755	258.6	3/14/77	1955	306.1
3/14/77	1757	195.5	3/14/77	1958	201.1
3/14/77	1804	301.7	3/14/77	2000	215.8
3/14/77	1805	333.1	3/14/77	2002	301.7
3/14/77	1807	308.5	3/14/77	2004	325.3
3/14/77	1809	258.6	3/14/77	2006	301.7
3/14/77	1810	272.1	3/14/77	2007	320.3
3/14/77	1812	308.4	3/14/77	2009	277.6
3/14/77	1814	291.2	3/14/77	2010	1095.6
3/14/77	1815	301.7	3/14/77	2012	205.1
3/14/77	1817	297.4	3/14/77	2014	315.4
3/14/77	1819	273.9	3/14/77	2015	258.6
3/14/77	1820	832.7	3/14/77	2016	1261.7
3/14/77	1822	191.0	3/14/77	2019	203.1
3/14/77	1824	297.4	3/14/77	2020	297.4

TABLE B-11. (Continued)

DATE	TIME	FLOW (LITERS/MIN.)	DATE	TIME	FLOW (LITERS/MIN.)
3/14/77	2022	277.6	3/14/77	2153	317.8
3/14/77	2025	157.1	3/14/77	2155	315.4
3/14/77	2026	333.1	3/14/77	2156	315.4
3/14/77	2028	289.1	5/2/77	1223	115.1
3/14/77	2031	198.3	5/2/77	1227	115.1
3/14/77	2034	187.5	5/2/77	1231	113.8
3/14/77	2035	308.4	5/2/77	1236	115.1
3/14/77	2037	263.5	5/2/77	1240	113.4
3/14/77	2039	317.8	5/2/77	1244	114.4
3/14/77	2042	219.1	5/2/77	1248	113.8
3/14/77	2044	289.1	5/2/77	1252	114.4
3/14/77	2046	196.4	5/2/77	1256	113.4
3/14/77	2049	178.7	5/2/77	1300	113.8
3/14/77	2050	717.8	5/2/77	1303	113.4
3/14/77	2052	203.1	5/2/77	1307	115.0
3/14/77	2054	306.1	5/2/77	1311	114.1
3/14/77	2056	273.9	5/2/77	1315	112.8
3/14/77	2058	242.0	5/2/77	1319	118.3
3/14/77	2059	717.8	5/2/77	1323	111.9
3/14/77	2101	195.5	5/2/77	1327	121.4
3/14/77	2102	826.1	5/2/77	1331	115.7
3/14/77	2104	185.9	5/2/77	1335	115.7
3/14/77	2107	195.5	5/2/77	1340	116.6
3/14/77	2110	195.5	5/2/77	1344	116.3
3/14/77	2112	198.3	5/2/77	1347	115.7
3/14/77	2115	200.1	5/2/77	1352	115.7
3/14/77	2117	202.1	5/2/77	1355	119.0
3/14/77	2119	201.1	5/2/77	1359	119.0
3/14/77	2121	203.1	5/2/77	1403	118.0
3/14/77	2124	202.1	5/2/77	1407	118.6
3/14/77	2126	260.2	5/2/77	1410	118.3
3/14/77	2128	293.2	5/2/77	1414	118.0
3/14/77	2130	310.7	5/2/77	1417	117.3
3/14/77	2132	191.8	5/2/77	1421	116.9
3/14/77	2135	183.4	5/2/77	1425	118.0
3/14/77	2137	287.2	5/2/77	1429	115.7
3/14/77	2139	293.2	5/2/77	1434	117.3
3/14/77	2140	289.1	5/2/77	1438	117.3
3/14/77	2142	322.7	5/2/77	1441	118.6
3/14/77	2144	308.4	5/2/77	1445	119.9
3/14/77	2145	301.7	5/2/77	1450	119.3
3/14/77	2148	303.9	5/2/77	1454	116.9
3/14/77	2149	299.6	5/16/77	1022	174.2
3/14/77	2151	315.4	5/16/77	1025	175.8

TABLE B-11. (Continued)

DATE	TIME	FLOW (LITERS/MIN.)	DATE	TIME	FLOW (LITERS/MIN.)
5/16/77	1028	185.0	5/16/77	1112	1301.1
5/16/77	1031	175.7	5/16/77	1113	1387.8
5/16/77	1034	175.7	5/16/77	1114	1387.8
5/16/77	1037	175.7	5/16/77	1115	1261.7
5/16/77	1039	175.7	5/16/77	1116	1435.7
5/16/77	1042	174.9	5/16/77	1117	1387.8
5/16/77	1045	175.7	5/16/77	1119	1387.8
5/16/77	1048	176.4	5/16/77	1120	1435.7
5/16/77	1050	171.3	5/16/77	1121	1387.8
5/16/77	1054	165.9	5/16/77	1122	1892.5
5/16/77	1056	173.5	5/16/77	1125	1810.3
5/16/77	1059	163.6	5/16/77	1127	1542.0
5/16/77	1101	991.3	5/16/77	1130	1486.9
5/16/77	1102	1387.8	5/16/77	1132	1387.8
5/16/77	1104	1343.1	5/16/77	1134	1486.9
5/16/77	1105	1387.8	5/16/77	1135	1665.4
5/16/77	1106	1343.1	5/16/77	1136	1343.1
5/16/77	1107	1343.1	5/16/77	1137	1261.7
5/16/77	1108	1387.8	5/16/77	1139	1261.7
5/16/77	1109	1486.9	5/16/77	1139	1387.8
5/16/77	1110	1435.8	5/16/77	1139	885.8
5/16/77	1111	1301.1	5/16/77	1140	1301.1
MINIMUM					109.2
AVERAGE					241.9
MAXIMUM					1968.5

TABLE B-12. STEAM, WATER, AND SEWER

	DOWNTIME	STANDBY	SCENARIO 1	SCENARIO 2	SCENARIO 3
REFUSE PROCESSED (Mg/hr)	0	0	27	32	36
STEAM PRODUCED (Mg/hr)	0	35	50	59	66
WATER					
Boiler Feedwater					
Steam	0	840,000	1,200,000	1,416,000	1,584,000
Constant Blowdown	0	92,400	132,000	155,760	174,240
Manual Blowdown	0	75,600	75,600	75,600	75,600
Fan Cooling	5,440	5,440	5,440	5,440	5,440
Shredder Cooling	73,480	73,480	73,480	73,480	73,480
Make Up	108,860	108,860	108,860	108,860	108,860
TOTAL	187,780	1,195,780	1,595,380	1,835,140	2,021,620
SEWER					
Constant Blowdown	0	92,400	132,000	155,760	174,240
Manual Blowdown	0	75,600	75,600	75,600	75,600
Fan Cooling	5,440	5,440	5,440	5,440	5,440
Shredder Cooling	73,480	73,480	73,480	73,480	73,480
Cooling System Blowdown	108,860	108,860	108,860	108,860	108,860
TOTAL	187,780	355,780	395,380	419,140	437,620

TABLE B-13. TEMPERATURE AND pH OF WASTEWATER EFFLUENT

DATE	TIME	pH	°C
1/31/77	1400	10.7	
1/31/77	1430	10.2	
1/31/77	1500	10.5	
1/31/77	1530	10.5	
1/31/77	1600	10.6	
1/31/77	1630	10.4	
1/31/77	1700	10.6	
1/31/77	1730	10.8	
2/01/77	730	6.5	
2/01/77	800	6.5	
2/01/77	830	6.8	
2/01/77	900	6.9	
2/01/77	930	7.2	
2/01/77	1000	6.8	
2/01/77	1030	7.0	
2/01/77	1100	-	
2/28/77	1030	9.2	
2/28/77	1100	9.2	
2/28/77	1130	9.1	
2/28/77	1200	8.9	
2/28/77	1230	9.1	
2/28/77	1300	8.9	
2/28/77	1330	8.8	
2/28/77	1400	8.8	
2/28/77	1430	9.0	
2/28/77	1500	8.9	
2/28/77	1530	8.9	
2/28/77	1600	8.1	
2/28/77	1630	7.9	
2/28/77	1700	8.9	
2/28/77	1730	8.8	
2/28/77	1800	8.7	
4/28/77	1035	10.8	41.7
4/28/77	1038	10.8	41.7
4/28/77	1041	10.6	41.7
4/28/77	1045	10.6	41.7
4/28/77	1046	10.5	41.7
4/28/77	1049	10.6	41.7
4/28/77	1053	10.6	41.7
4/28/77	1056	10.6	41.7
4/28/77	1058	10.6	41.7
4/28/77	1100	10.6	41.7

(continued)

TABLE B-13. (Continued)

DATE	TIME	pH	°C
4/28/77	1103	10.6	42.2
4/28/77	1106	10.6	42.2
4/28/77	1109	10.6	42.2
4/28/77	1112	10.6	42.2
4/28/77	1114	10.4	42.2
4/28/77	1115	10.4	37.2
4/28/77	1117	10.3	35.6
4/28/77	1118	10.3	35.0
4/28/77	1122	10.4	34.4
4/28/77	1124	10.4	35.0
4/28/77	1127	10.5	36.7
4/28/77	1132	10.5	38.3
4/28/77	1134	10.5	37.2
4/28/77	1137	10.6	38.3
4/28/77	1140	10.6	38.3
4/28/77	1142	10.6	41.7
4/28/77	1145	10.5	41.7
4/28/77	1149	10.5	40.6
4/28/77	1150	10.5	41.1
4/28/77	1154	10.5	41.1
4/28/77	1157	10.5	41.1
4/28/77	1159	10.5	41.1
4/28/77	1202	10.5	41.1
4/28/77	1204	10.5	41.1
4/28/77	1207	10.5	41.1

TABLE B-14. ANALYSIS OF THE WASTEWATER EFFLUENT

Date		2/1/77	3/1/77	4/29/77	Average
Alkalinity	(mg/l)	110	30	102	81
BOD ₅	(mg/l)	4	3	64	24
COD	(mg/l)	30	30	184	81
Chlorides	(mg/l)	54	418	268	247
Suspended Solids	(mg/l)	101	76	152	110
Total Solids	(mg/l)	1240	1080	962	1094
Volatile Solids	(mg/l)	68	785	250	368
Volatile Suspended Solids	(mg/l)	39	15	54	36
Hardness	(mg/l)	-	370	84	227
Sulfide	(mg/l)	0.0	0.0	0.0	0.0
Sulfite	(mg/l)	0.7	0.0	-	0.4
Sulfate	(mg/l)	250	45	89	127
Iron	(mg/l)	7.6	0.89	1.75	3.4
TKN	(mg/l)	1.8	0.8	8.1	3.6
Total Phosphorous	(mg/l)	0.74	0.0	0.57	0.4
Standard Plate Count	(Organism/ml)	7600	200,000	700	69,000
Total Coliform	(MPN/100 ml)	5	460	0	155
Fecal Streptococci	(MPN/100 ml)	79	14	460	184
Lead	(mg/l)	-	0.1	0.1	0.1
Mercury	(mg/l)	-	0.0	0.004	0.002

SECTION B-3

WASTE PREPARATION SUBSYSTEM

REFUSE COMPOSITION

The composition of the refuse was determined by two different methods at different locations in the process stream. The composition of the refuse in the storage pit was determined by manual and photosorts, and by moisture and bulk density analysis of the manually sorted categories. The shredded refuse on the kiln feed conveyor was subjected to moisture, proximate and ultimate analyses.

Sorting Methods

A 45 - 90 kg (100 - 200 lb) sample for sorting was obtained from the storage pit by using a front endloader, or alternately by placing the refuse within a randomly chosen area on a canvas tarp. The sample was then placed on a tarp between two rows of 5 - 208 liter (55 gallon) drums. Each drum was labeled for a specific waste category. All the trash bags were then split open, the contents dumped back onto the pile and the bag placed back into the pile. This point 2 photo slides of the sample pile of refuse were taken (Figure B-1). The sample pile of refuse was then sorted into categories until the pile contained only small fines less than 2.5 cm (1 in.). The total mass of each category was determined by weighing, and the bulk density was determined selectively by measuring the volume of sample for each category. The photo sort slides were analyzed by projecting the slide on a backlighted screen marked with a 2.5 cm (1 in.) grid. The type of waste (category) under each mode (cross in the grid) was observed and recorded. The number of counts for each category was multiplied by the material bulk density to obtain a relative weight. This relative weight was divided by the sum of all the relative weights to obtain the mass percent for that category. The photo sort did not compare directly to the manual sort, as shown in Table B-15, and should not be relied upon as a precise method for determining refuse composition.

The glass and iron may be low in the photo sorts due to settling within the pile or misreading due to attached paper. Organics are small and hard to see in a photo sort, often wrapped in paper or placed in cans.

The "other metals" category typically included in composition analyses was eliminated because there is usually only a trace amount (less than 1 percent) in a 90 kg (200 lb) sample.



Figure B-1. Photo sort picture.

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TABLE B-15. A COMPARISON OF MANUAL AND PHOTO SORT

Category	Percent of Total Mass			
	Sample A		Sample B	
	Manual	Photo	Manual	Photo
Paper	34	73	43	67
Organics	19	5	14	0
Wood	3	0	3	0
Magnetics	8	3	9	4
Aluminum	3	1	2	2
Glass	14	3	19	8
Plastic	16	14	7	7
Textiles	3	0	3	13
Inert	1	0	0	0

An attempt was made to determine the composition of the "fines" category by manually sorting the fines in the size range of 0.5 cm (0.2 in.) to 2.5 cm (1 in.) (Table B-16).

The fines from Sample B with a size of less than 0.5 cm (0.2 in.) had an estimated composition of 60 percent organics and 40 percent glass. While the omission of the fines from sorting would result in a systematic error of lower organic and glass concentrations. The average component properties of the refuse as measured by manual sorts are shown in Table B-17.

Physical and Chemical Analysis

Shredded refuse samples from the kiln feed conveyor were collected and dried in an oven at a temperature of 103°C (217°F). The shredded refuse samples were weighed before and after drying, and the results are shown in Table B-18. The dried shredded refuse samples were combined to form a weekly composite sample which was sent to an outside lab for proximate, ultimate, and ash analysis. The proximate analyses, including some reported by Monsanto, are shown in Table B-19. The actual analyses reported by the labs were corrected to include the separated matter (metal and glass) as ash, and to the average, "as received" moisture content. The ultimate analyses including those reported by Monsanto, are shown in Table B-20. In order to compare the proximate and ultimate analyses with the manual sort data, the results of the manual sorts were used to back calculate a hypothetical proximate and ultimate analysis. The results, shown in Table B-21, reveal that the two techniques yield different compositions. Both techniques are questionable because of the relatively small sample size and heterogeneity of the refuse.

The ash analyses of the refuse are shown in Table B-22, while the optical emission spectrography analysis of the refuse is shown in Table B-23.

REFUSE BULK DENSITY

As discussed in Volume II, the refuse bulk densities were measured at various stages of preparation. Tables B-24 through B-26 detail the bulk density values presented in Section 3 of Volume II. Table B-25 also presents bulk densities measured in the storage and recovery unit. The bulk densities were measured by filling a 0.04 m³ (1.5 ft.³) box with the samples and then weighing the sample.

The size distribution of the refuse before and after shredding was measured by sieve analysis. Five sieves were used; 152.4 mm (6 in.), 101.6 mm (4 in.), 50.8 mm (2 in.), 25.4 mm (1 in.), and 5.1 mm (0.2 in.). The results of the sieve analysis are shown in Table B-27. Figure B-2 reveals that the refuse lacks an uniform size distribution both before and after shredding.

Tables B-28 and B-29 detail diesel fuel consumption data that were presented as averages in Section 3, Volume II of the report. Total consumption was measured by daily readings of the totalizer on the diesel fuel pump. Some of the readings were taken from the city daily log, but the majority were recorded by SYSTECH. The consumption of diesel fuel is not presented on

TABLE B-16. MANUAL SORT OF REFUSE FINES

Category	Percent of Total Mass	
	Sample A	Sample B
Paper	10	2
Organics	34	23
Plastics	5	1
Textiles	1	0
Wood	1	0
Glass	39	71
Magnetics	2	0
Aluminum	2	0
Inerts	7	2

TABLE B-17. BALTIMORE REFUSE AVERAGE COMPONENT PROPERTIES

Component	Weight % of Total	Moisture (Weight%)	Bulk Density (kg/m ³)
Paper	43	21.4	60.9
Organics	17	56.7	272.3
Plastics	7	5.5	33.6
Textiles	6	16.4	110.5
Wood	2	8.9	144.2
Glass	15	0.0	408.5
Iron	7	10.4	128.1
Aluminum	2	8.5	142.6
Inerts	1	3.0	929.1

TABLE B-18. SHREDDED REFUSE MOISTURE CONTENT

Date	% Moisture	Date	% Moisture
11/12/76	26	2/06/77	21
11/15/76	18	2/22/77	19
11/16/76	16	2/25/77	21
11/29/76	28	2/28/77	24
12/07/76	25	3/08/77	16
12/09/76	21	3/09/77	23
12/10/76	21	3/11/77	21
12/12/76	15	3/14/77	28
12/13/76	9	3/15/77	27
12/14/76	3	3/17/77	24
12/16/76	12	4/27/77	22
12/17/76	27	4/28/77	16
01/18/77	14	4/29/77	27
01/19/77	24	5/02/77	22
01/20/77	26	5/03/77	23
01/23/77	25	5/05/77	26
01/24/77	27	6/06/77	5
01/31/77	18	5/09/77	18
02/01/77	20	5/10/77	20
02/03/77	19	5/11/77	20
02/04/77	20	5/12/77	15
02/05/77	20	5/13/77	21
Average		20.30	
Standard Deviation		5.65	

TABLE B-19. PROXIMATE ANALYSIS OF REFUSE

DATE TIME	3/25/75† 1030				†				4/12/75† 1500			
	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	39.70	-	10.79	-	27.89	-	16.88	-	59.73	-	59.73
Volatile Matter	%	29.19	48.40	42.72	47.89	34.93	48.44	49.65	48.44	11.65	49.65	11.65
Fixed Carbon	%	4.08	6.76	4.30	4.81	4.11	5.70	9.68	5.70	28.62	9.68	28.62
Ash	%	27.04	44.84	42.20	47.30	33.11	45.92	23.79	45.92	0.14	23.79	0.14
Sulfur	%	0.05	0.09	0.12	0.14	0.14	0.19	0.12	0.19	13.53	0.12	13.53
Heat Content	MJ/kg	7.14	11.85	9.46	10.57	8.10	11.23	11.25	11.23	-	11.25	-
Total Separated Matter	%	-	9.20	-	11.00	2.10	-	1.53	-	-	1.53	-
DATE TIME	4/13/75† 1400				4/18/75† 1520				4/22/75† 1030			
	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	24.09	-	16.96	-	22.22	-	11.74	-	57.81	-	57.81
Volatile Matter	%	35.24	46.42	40.30	48.53	39.80	51.17	51.02	51.17	9.65	51.02	9.65
Fixed Carbon	%	6.43	8.47	5.96	7.12	8.42	10.83	8.52	10.83	32.54	8.52	32.54
Ash	%	34.24	45.11	36.78	44.29	29.55	37.99	28.72	37.99	0.18	28.72	0.18
Sulfur	%	0.12	0.16	0.12	0.14	0.18	0.23	0.16	0.23	11.64	0.16	11.64
Heat Content	MJ/kg	8.33	10.97	9.10	10.96	9.87	12.69	10.27	12.69	-	10.27	-
Total Separated Matter	%	1.80	-	4.07	-	1.72	-	5.04	-	-	5.04	-

(continued)

TABLE B-19. (Continued)

DATE TIME	4/22/75† 2300	5/10/75† 1000	5/12/75† 0210	5/12/75† 1950
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	25.68	-	-
Volatile	%	37.81	50.87	39.32
Fixed Carbon	%	6.23	8.38	3.74
Ash	%	30.27	40.73	57.35
Sulfur	%	0.11	0.15	0.20
Heat Content	MJ/kg	8.90	11.98	9.38
Total Separated Matter	%	5.28	-	-
			AS REC'D	DRY
			22.25	16.08
			33.56	33.00
			6.99	3.14
			37.21	48.13
			0.15	0.17
			9.34	7.87
			7.33	12.60
			-	-

DATE TIME	6/20/75§ 0335	6/21/75§ 0820	6/11/75§	11/15/76-11/21/76 COMPOSITE
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	11.57	-	-
Volatile	%	43.30	48.97	28.68
Fixed Carbon	%	9.09	10.28	6.99
Ash	%	36.40	41.16	63.35
Sulfur	%	0.11	0.12	6.80
Heat Content	MJ/kg	12.27	13.88	6.80
Total Separated Matter	%	13.26	-	-
			AS REC'D	DRY
			27.42	11.45
			32.10	25.40
			3.18	6.19
			37.29	56.10
			0.11	0.06
			8.89	6.02
			8.04	46.72
			-	-
			23.50	-
			57.51	28.68
			10.72	6.99
			8.27	63.35
			0.15	6.80
			13.06	6.80
			17.07	-
			-	-

(continued)

TABLE B-19. (Continued)

DATE TIME	12/12/76-12/18/76† COMPOSITE	1/16/77-1/22/77‡ COMPOSITE	2/1/77-2/5/77§ COMPOSITE
Moisture	% 12.00	21.33	19.75
Volatile Matter	% 40.31	33.36	20.46
Fixed Carbon	% 1.13	4.36	21.55
Ash	% 46.56	40.95	38.26
Sulfur	% 0.13	0.14	0.13
Heat Content	MJ/kg 12.75	7.80	8.83
Total Separated Matter	% -	-	27.79

48

* Included as Ash.

† Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 35.

§ Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 1.

¶ Moisture corrected to moisture measured on site.

TABLE B-20. ULTIMATE ANALYSIS OF REFUSE

DATE TIME	6/20/75* 0335	6/21/75* 0820	6/11/76† 0515	11/15/76-11/21/76 COMPOSITE	12/12/76-12/18/76 COMPOSITE	1/16/77-1/22/77 COMPOSITE
Carbon %	31.42	24.99	40.67	20.31	38.60	29.10
Hydrogen %	0.53	0.46	5.58	1.94	2.00	1.00
Nitrogen %	4.47	3.68	6.65	0.19	0.58	0.26
Oxygen %	22.78	19.33	42.09	13.65	5.80	17.40
DATE TIME	2/1/77-2/5/77 COMPOSITE					
Carbon %	32.42					
Hydrogen %	2.14					
Nitrogen %	0.40					
Oxygen %	17.21					

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 35.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 1.

TABLE B-21. CALCULATED REFUSE COMPOSITION

Category	Total (Wt. %)	Moisture* (Wt. %)	Volatile Matter* (Wt. %)	Fixed Carbon* (Wt. %)	Ash* (Wt. %)	Heat Content* (MJ/kg)
Paper	43	10.2	75.9	8.4	5.4	15.8
Organics	17	72.0	20.3	3.3	4.5	25.5
Plastics	7	5.5	80.0	4.5	10.0	31.6
Textiles	6	10.0	84.3	3.5	2.2	16.0
Wood	2	20.0	67.9	11.3	0.8	16.0
Glass	15	2.0	0.4	0.4	97.2	0.2
Magnetics	7	3.0	0.5	0.5	96.0	0.3
Aluminum	2	3.0	0.5	0.5	96.0	0.3
Inerts	1	2.0	0.4	0.4	97.2	0.2
Total	100	18.61	48.21	5.03	28.13	11.3

	Carbon* (Wt. %)	Hydrogen* (Wt. %)	Oxygen* (Wt. %)	Nitrogen* (Wt. %)	Sulfur* (Wt. %)
Paper	43.4	5.8	44.3	0.3	0.2
Organics	45.0	6.4	28.8	3.3	0.5
Plastics	60.0	7.2	22.6	0.0	0.0
Textiles	55.0	6.6	31.2	4.6	0.1
Wood	50.5	6.0	42.4	0.1	0.1
Glass	0.6	0.0	0.1	0.0	0.0
Magnetics	0.8	0.0	0.2	0.0	0.0
Aluminum	0.8	0.0	0.2	0.0	0.0
Inerts	0.6	0.0	0.1	0.0	0.0
Total	26.81	3.12	22.36	.52	.10

* J. M. Bell, "Characteristics of Municipal Refuse", Proceedings of the National Conference on Solid Waste Resources, American Public Works Association, February, 1964.

TABLE B-22. ASH ANALYSIS OF REFUSE

DATE TIME	3/25/75* 1030	11/15/76-11/21/76 COMPOSITE	12/12/76-12/18/76 COMPOSITE	1/16/77-1/22/77 COMPOSITE	2/1/77-2/5/77 COMPOSITE
	%	%	%	%	%
Alumina	5.02	1.11	3.10	3.50	44.85
Chromic Oxide	0.04	-	-	-	-
Cupric Oxide	0.11	-	-	-	-
Ferric Oxide	1.73	64.78	4.14	1.92	1.28
Lead Oxide	0.11	-	-	-	-
Lime	11.51	2.51	5.71	3.57	5.43
Manganese Dioxide	0.11	-	-	-	-
Magnesia	1.60	0.29	0.66	0.68	0.72
Nickel Oxide	0.01	-	-	-	-
Phosphorous Pentoxide	-	0.35	0.66	0.66	0.51
Potassium Oxide	1.02	0.22	0.60	0.46	0.61
Silica	62.10	26.12	74.30	74.80	38.74
Sodium Oxide	9.00	2.05	6.04	7.08	3.82
Sulfur Trioxide	-	0.29	0.57	0.63	0.54
Titania	0.47	0.75	0.40	0.47	0.50
Zinc Oxide	2.02	-	-	-	-

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 36.

TABLE B-23. OPTICAL EMISSION SPECTROGRAPHY ANALYSIS OF FEED SAMPLE*

Element	%
Aluminum	1 - 10
Antimony	0.005
Arsenic	0.005
Barium	0.100 - 1.000
Beryllium	0.001
Bismuth	0.001
Boron	0.030 - 0.300
Cadmium	0.001
Calcium	1 - 10
Chromium	0.010 - 0.100
Cobalt	0.001 - 0.010
Copper	0.100 - 1.000
Germanium	0.001
Iron	1 - 10
Lead	0.050 - 0.500
Magnesium	0.100 - 1.000
Manganese	0.050 - 0.500
Molybdenum	0.005 - 0.050
Nickel	0.010 - 0.100
Phosphorus	0.010 - 0.100
Potassium	0.500 - 5.000
Silicon	3 - 30
Silver	0.001 - 0.010
Sodium	3 - 30
Strontium	0.000 - 0.100
Thallium	0.001
Tin	0.010 - 0.100
Titanium	0.100 - 1.000
Vanadium	0.001 - 0.010
Zinc	0.500 - 5.000

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 36. 3/25/75, 1030.

TABLE B-24. REFUSE BULK DENSITIES

Before Shredding		After Shredding	
Date	kg/m ³	Date	kg/m ³
4/27/77	165.0	11/16/76	48.1
4/27/77	96.1	12/07/76	76.9
4/28/77	133.0	12/09/76	49.7
4/29/77	84.9	12/10/76	38.4
5/02/77	100.9	12/11/76	38.4
5/03/77	176.2	12/13/76	73.7
5/04/77	165.0	12/14/76	59.3
5/05/77	116.9	12/15/76	68.9
5/06/77	105.7	12/17/76	40.0
5/09/77	96.1	12/18/76	22.4
5/10/77	121.7	12/19/76	40.0
5/11/77	112.1		
5/12/77	96.1		
5/13/77	137.8		
Mean	122.0	Mean	50.5
Standard deviation	28.4	Standard deviation	16.3
Minimum	84.9	Minimum	22.4
Maximum	176.2	Maximum	73.7

TABLE B-25. REFUSE BULK DENSITIES

DATE	LOCATION	Kg/m ³
4/15/75	Outfeed Conveyor*	201.8
4/15/75	Atlas Bucket Chain*	128.0
4/15/75	Atlas Pile*	193.8
12/22/76	Outfeed Conveyor	102.5
12/22/76	Atlas Pile	205.0
12/22/76	Atlas Pile (bottom core)	397.3
4/4/76	Storage Pit (loose)	144.2
4/4/76	Storage Pit (dense)	498.2

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 34.

TABLE B-26. REFUSE BULK DENSITIES AFTER SHREDDING AND STORAGE

Storage* (450 - 720 Mg)		Storage (180 - 450 Mg)		No Storage	
Date	kg/m ³	Date	kg/m ³	Date	kg/m ³
4/18/75	143.7	1/18/77	68.8	4/27/77	41.6
4/21/75	143.7	1/19/77	104.0	4/28/77	105.7
4/27/75	192.2	1/20/77	104.0	4/29/77	112.1
4/27/75	167.7	1/23/77	120.0	5/02/77	105.7
4/28/75	120.1	1/24/77	104.0	5/04/77	105.7
4/28/75	185.8	1/31/77	104.0	5/05/77	89.7
4/28/75	173.0	2/01/77	128.0	5/06/77	80.1
4/28/75	129.7	2/03/77	80.0	5/09/77	80.1
4/28/75	198.6	2/04/77	48.0	5/10/77	100.9
5/10/75	125.7	2/22/77	105.6	5/11/77	80.1
5/12/75	149.8	2/25/77	160.0	5/12/77	64.1
5/12/75	131.8	2/28/77	112.0	5/13/77	126.5
5/19/75	133.0	3/08/77	112.0		
5/29/75	145.8	3/09/77	224.0		
5/31/75	126.5	3/11/77	144.0		
6/01/75	120.1	3/14/77	160.0		
6/02/75	122.9	3/15/77	112.0		
6/16/75	154.4	3/17/77	144.0		
6/20/75	119.8				
6/21/75	205.0				
6/28/75	176.2				
7/02/75	155.7				
7/17/75	101.9				
7/23/75	161.8				
Mean	148.3		117.5		91.0
Standard Deviation	27.4		39.4		22.3
Minimum	101.9		48.0		41.6
Maximum	205.0		224.0		126.5

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 34.

TABLE B-27. BALTIMORE REFUSE SIZE DISTRIBUTION

Before Shredding					
Date	4/28/77	5/5/77			
Size Range (mm)	Weight in Grams		Weight %		
Size > 152.4	2043.0	999.8	24		
101.6 < Size < 152.4	908.0	1362.0	18		
50.8 < Size < 101.6	908.0	2133.8	24		
25.4 < Size < 50.8	454.0	1089.6	12		
5.1 < Size < 25.4	908.0	817.2	14		
Size < 5.1	454.0	454.0	7		
After Shredding					
Date	11/29/76	12/7/76	12/8/76	12/10/76	1/23/77
Size Range (mm)	Weight in Grams				
Size > 152.4	0	0	0	0	0
101.6 < Size < 152.4	0	13.6	31.8	0	18.2
50.8 < Size < 101.6	276.9	195.2	45.4	9.1	136.2
25.4 < Size < 50.8	172.5	272.4	86.3	4.5	267.9
5.1 < Size < 25.4	172.5	290.6	95.3	63.6	622.0
Size < 5.1	149.8	227.0	72.6	40.9	444.9
					967.0
					2120.2
					38

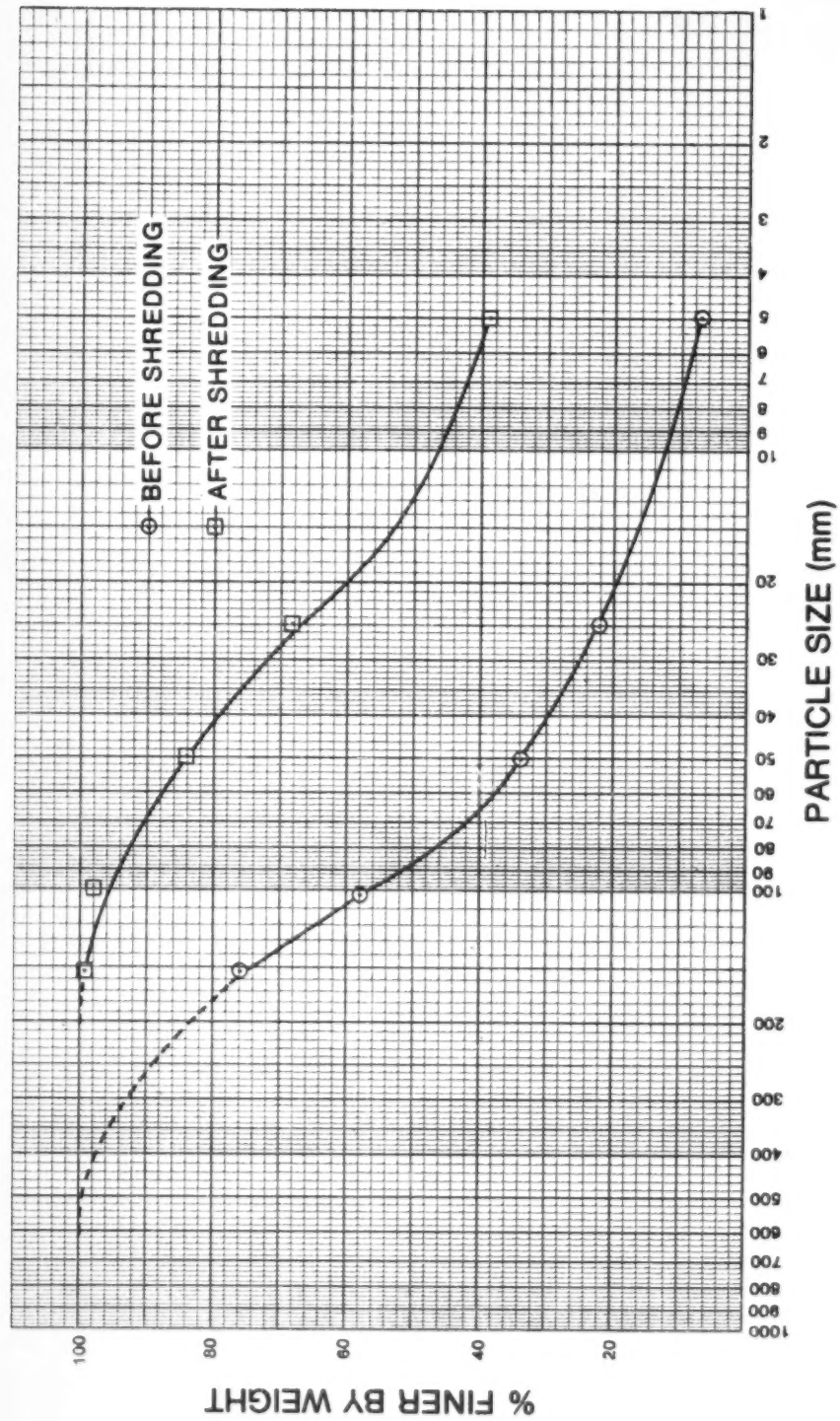


Figure B-2. Refuse size distribution.

TABLE B-28. DIESEL FUEL CONSUMPTION WHILE PROCESSING*

PERIOD	DAYS	REFUSE PROCESSED (Mg)	TOTAL CONSUMPTION (LITERS)	CONSUMPTION PER Mg (LITERS/MG)	CONSUMPTION PER DAY (LITERS/DAY)
11/ 6/76-11/ 7/76	2	299	462	1.5	231
11/12/76-11/16/76	5	2560	1,457	0.6	291
11/25/76-11/29/76	5	1751	1,018	0.6	204
12/ 7/76-12/19/76	18	5365	2,979	0.6	165
1/ 8/77- 1/24/77	17	5817	3,592	0.6	211
1/31/77- 2/6/77	7	3341	1,647	0.5	235
2/22/77- 3/17/77	24	10,560	5,088	0.5	212
TOTAL	78	29,693	16,243	0.55	208

* City Daily Log.

TABLE B-29. DIESEL FUEL CONSUMPTION DURING DOWNTIME*

PERIOD	DAYS	TOTAL CONSUMPTION (LITERS)	CONSUMPTION PER DAY (LITERS/DAY)
11/ 4/76-11/ 5/76	2	0	0
11/19/76-11/24/76	6	333	56
11/30/76-12/ 5/76	6	159	26
12/24/76- 1/ 7/77	15	1,473	98
1/25/77- 1/27/77	3	231	77
2/10/77- 2/21/77	12	621	52
TOTAL	44	2,816	64

* City Daily Log.

a daily basis because it is meaningless because filling of the bulldozer fuel tanks was only done every 3 days. The amount of refuse processed was determined from city daily operation reports.

Table B-30 lists the duct flows within the dust collection system as measured by Monsanto when initially balancing the system.

Table B-31 details the composition data of the magnetic drum discharge summarized in Section 2 of Volume II. As indicated by the table, only one manual sort was obtainable due to the short operating period of the magnet. The amount of shredded refuse separated during operation was determined by weighing the separated refuse contained in the metal transfer truck using the truck scale. This data along with the amount of shredded refuse fed to the magnetic drum was obtained from the city daily operation report. The total separated magnetic material was calculated to be 5.4 percent of the feed stream. The percent of material in each category removed by the magnetic drum separator was calculated as follows:

$$\frac{\text{Wt. \% of category "A" in separated refuse} \times \text{Total \% of refuse separated}}{\text{Wt. \% of category "A" in incoming stream}}$$

The power demand of various motors of the storage and recovery unit as a function of various output parameters is shown in Table B-32.

TABLE B-30. DUST COLLECTION SYSTEM FLOWS*

Sample Point	Air Flow (m ³ /min)
Shredder feed conveyor discharge	40.8
Shredded refuse collecting conveyor	90.9
Shredder dust collector	135.1
Shredder feed conveyor discharge	35.4
Shredded refuse collecting conveyor	78.7
Shredded refuse elevating conveyor	20.1
Shredder dust collector	134.8
Shredders	266.2
Storage and recovery unit	26.9
Storage and recovery unit dust collector	---
Transfer tower inlet	258.3
Shredded refuse elevating conveyor	13.6
Shredded refuse transfer conveyor	13.6
Magnetic drum separator	33.1
Storage and recovery unit	13.6
Kiln feed conveyor	13.6
Storage and recovery unit drag conveyor	22.4
Transfer tower dust collector	54.1
Transfer tower outlet	342.6
Ram feeders	---
Kiln feed dust collector	---
Dust collection fan inlet	365.3
Dust collection fan outlet	351.1

* Monsanto Modification Evaluation, F01-201, 11/1/76, Unpublished data.

TABLE B-31. COMPOSITION OF MAGNETIC DRUM DISCHARGE

Category	Weight %*	% Removed†
Paper	6.8	0.9
Organics	2.8	0.9
Plastics	0.3	0.2
Textiles	0.8	0.7
Wood	0.0	0.0
Glass	0.6	0.2
Magnetic metals	88.5	68.5
Aluminum	0.0	0.0
Inerts	0.0	0.0

* Systech Manual Sort, 11/7/76.

† 5.4 percent of shredded refuse separated (City Daily Operation Report, 11/6/76 - 11/7/76).

TABLE B-32. ATLAS RUNOUT DATA*

Date	Time	Rate (Mg/hr)	Waste Age (Days)	Shredder (on/off)	Buckets Con- tacting Pile (Per Chain)	Refuse in Silo (Mg)	Pile Diameter (m)	Sweep Master (kw)	Sweep Slave (kw)	Drag (kw)
6/07/76	1725	27.2	0.5	On	13	540	22	36.8	36.8	12.7
	1830	27.2	0.5	On	12	540	30	38.7	40.7	12.0
	2000	27.2	0.5	On	12	540	33	42.6	44.9	11.6
	2200	27.2	0.5	On	13	635	30	38.7	40.7	11.2
6/08/76	1300	22.7	1.0	Off	11	635	21	29.0	36.8	10.5
	1400	27.2	1.0	Off	11	610	21	30.2	32.9	9.7
	1515	24.5	1.0	Off	9		21	32.9	36.8	12.0
	1620	26.3	1.0	Off	12	540	21	34.8	38.7	11.2
6/09/76	1840	28.1	1.0	Both On	10	590	21	27.1	29.0	10.1
	2115	28.1	1.5	Both On	9	590	18	27.1	31.0	10.8
	2315	26.3	1.5	Both On	10	650	20	31.0	34.8	11.2
	0300	27.2	1.5	Both On	10		20	21.3	29.0	9.7
6/09/76	1500	24.5	2.0	Off	11	635	21	34.8	38.7	12.7
	1600	26.3	2.0	Off	11	610	21	31.0	32.9	12.0
	1700	25.4		On	10	580	21	29.0	34.8	11.6
	1900	25.4	2.0	Both On	11	635	22	32.9	34.8	11.6
6/10/76	2045	27.2	2.0	Both On	12	680	21	31.0	32.9	11.2
	0000	30.8	2.0	Both On	12		23	31.0	34.8	10.5
	0200	25.4	2.0	Both On	13		21	32.9	36.8	11.2
	0400	30.8	2.0	Off	11		20	29.0	31.0	12.7
6/10/76	0600	29.0	2.0	Off	10		18	33.7	38.7	11.2
	0800	25.4	3.0	Off	10	635	16	21.3	27.1	12.0
	1030	26.3		On	11		17	29.0	32.9	11.2
	2130	23.6	2.0	Off	9	450	18	27.1	31.0	13.1
6/10/76	0100	24.5	2.0	Off	7		17	19.4	21.3	9.7
	0310	19.0	2.0	Off	7		15	19.4	23.2	11.2
	0700	22.7	2.0	Off	7		15	19.4	23.2	11.2
	1200	26.3	3.0	On	10	635	17	29.0	32.9	10.8

* Monsanto Modification Evaluation, A09-103, 6/12/76, Unpublished data.

SECTION B-4

THERMAL PROCESSING SUBSYSTEM

PLANT AVAILABILITY AND THROUGHPUT

The plant throughput was shown graphically in Figure 8 of Volume I, a cumulative plot of refuse processed versus time. The data used to develop this graph is detailed in the operation summary shown in Table B-33. The plant availability is shown by the daily operating time which increases generally throughout the periods. All dates not shown are periods of downtime.

FUEL OIL CONSUMPTION

The daily fuel oil consumption (Table B-34) was determined from the daily totalizer readings. These readings were made at or shortly after 7:00 a.m. The daily fuel oil consumption was from 7:00 a.m. of one day to 7:00 a.m. of the next day. This does not correlate with the operation summary (Table B-33) which has a daily period beginning and ending at midnight. The amount of refuse fired daily and the number of standby hours per day in Table B-34 are taken from Table B-33 to show the relationship between fuel oil consumption and the amount of refuse fired daily and the number of standby hours.

Using the hourly readings of the fuel oil totalizer and the city daily data sheets the hourly fuel oil consumption during both standby and operating conditions is shown in Tables B-35 and B-36 respectively. Table B-36 reveals that the fuel oil consumption during operating conditions is independent of the feed rate. The consumption depends upon the minimum firing rate of the burners. During the period from November 12 to December 14, 1976 the consumption averaged 723 liters per hour (194 gph). The minimum firing rates of certain burners was reduced and the operating fuel oil consumption dropped to an average of 262 liters per hour (69 gph) during the period of January 13 to March 13, 1977. The city then raised the minimum firing rates of the burners to maintain a stable flame. During the period from March 17 to May 13, 1977, the operating fuel oil consumption averaged 639 liters per hour (169 gph).

Two analyses of the No. 2 fuel oil are shown in Table B-37.

TABLE B-33. OPERATION SUMMARY

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
01/05/75	1.0	18.1	18.1	18.1
01/07/75	1.0	22.7	22.7	40.8
01/09/75	3.0	90.7	30.2	131.5
01/30/75	1.0	27.2	27.2	158.7
02/19/75	1.3	51.7	41.4	210.4
02/21/75	0.5	15.4	30.8	225.8
03/03/75	6.5	205.9	31.7	431.7
03/13/75	11.0	379.2	34.5	810.9
03/14/75	10.5	362.0	34.5	1,172.9
03/24/75	12.0	402.8	33.6	1,575.7
03/25/75	12.0	402.8	33.6	1,978.5
03/31/75	2.0	68.9	34.5	2,047.4
04/01/75	1.5	51.7	34.5	2,099.1
04/09/75	7.0	205.0	29.3	2,304.1
04/10/75	6.0	176.0	29.3	2,480.1
04/14/75	3.0	95.3	31.3	2,575.4
04/15/75	3.0	95.3	31.8	2,670.7
04/18/75	7.5	272.2	36.3	2,942.9
04/22/75	7.0	203.2	29.0	3,146.1
04/23/75	6.0	174.2	29.0	3,320.3
04/27/75	16.0	420.9	26.3	3,741.2
04/28/75	16.0	420.9	26.3	4,162.1
05/10/75	15.0	340.2	22.7	4,502.3
05/11/75	8.5	238.6	28.1	4,740.9
05/12/75	8.0	225.0	28.1	4,965.9
05/14/75	3.5	95.3	27.2	5,061.2
05/15/75	3.0	81.6	27.2	5,142.8
05/19/75	11.0	297.6	27.1	5,440.4
05/20/75	10.0	271.3	27.1	5,711.7
05/30/75	14.0	300.3	21.4	6,012.0
05/31/75	11.0	325.7	29.6	6,337.7
06/01/75	6.5	130.6	20.1	6,468.3
06/02/75	21.5	673.1	31.3	7,141.4
06/03/75	10.0	83.5	8.4	7,224.9
06/12/75	20.0	515.3	25.8	7,740.2
06/13/75	20.0	514.4	25.7	8,254.6
06/14/75	0.5	13.6	27.2	8,268.2
06/15/75	8.2	205.0	25.0	8,473.2
06/16/75	10.0	280.3	28.0	8,753.2
06/19/75	10.2	286.7	28.1	9,039.9
06/20/75	14.5	306.6	21.1	9,346.5
06/21/75	4.5	80.7	17.9	9,427.2

TABLE B-33. (Continued)

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
06/27/75	14.0	383.7	27.4	9,810.9
06/28/75	12.0	307.5	25.6	10,118.4
07/01/75	3.0	80.7	26.9	10,198.4
07/02/75	15.3	388.3	25.4	10,586.7
07/07/75	20.0	359.3	18.0	10,946.0
07/08/75	11.2	67.1	6.0	11,013.1
07/09/75	24.0	126.1	5.3	11,139.2
07/10/75	7.5	29.0	3.9	11,168.2
07/14/75	2.0	50.8	25.4	11,219.0
07/17/75	19.5	480.8	24.7	11,699.8
07/18/75	14.0	342.9	24.5	12,042.7
07/19/75	3.0	85.3	28.4	12,128.0
07/23/75	11.3	280.3	24.8	12,408.3
07/24/75	14.5	386.5	26.7	12,794.8
07/25/75	20.7	558.8	27.0	13,353.6
07/26/75	12.0	352.0	29.3	13,705.6
07/29/75	8.7	237.7	27.3	13,943.3
07/30/75	21.7	519.8	35.9	14,463.1
07/31/75	14.5	444.5	30.7	14,907.6
08/24/75	14.0	454.5	32.5	15,362.1
08/25/75	3.0	119.8	39.9	15,481.9
08/29/75	7.5	271.3	36.2	15,753.2
08/30/75	15.0	468.1	31.2	16,221.3
08/31/75	6.0	209.6	34.9	16,430.9
09/01/75	21.0	682.2	32.5	17,113.1
09/10/75	21.3	747.5	35.1	17,860.6
09/11/75	9.5	319.3	33.6	18,179.9
09/12/75	9.0	316.6	35.2	18,496.5
09/13/75	12.5	455.4	36.4	18,951.9
09/14/75	8.0	269.4	33.7	19,221.3
09/15/75	11.3	352.0	31.1	19,573.3
09/16/75	5.2	69.1	13.4	19,642.4
09/17/75	12.2	411.9	33.8	20,054.3
09/25/75	20.0	352.9	17.6	20,407.2
09/26/75	19.4	342.9	17.7	20,750.1
05/10/76	8.0	136.1	17.0	20,886.2
06/07/76	8.0	213.2	26.6	21,099.4
06/08/76	14.0	414.6	29.6	21,514.0
06/09/76	16.0	423.7	26.5	21,937.7
06/10/76	20.0	490.8	24.5	22,428.5
06/11/76	0.5	13.6	27.2	22,442.1
06/13/76	6.0	164.2	27.4	22,606.3
06/14/76	13.0	341.1	26.2	22,947.4

TABLE B-33. (Continued)

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
06/21/76	11.5	303.0	26.3	23,250.4
06/22/76	14.0	445.4	31.8	23,695.8
06/23/76	20.0	506.2	25.3	24,202.0
06/24/76	4.0	88.0	22.0	24,290.0
06/25/76	6.0	167.8	28.0	24,457.8
07/07/76	4.0	102.5	25.6	24,560.3
07/08/76	17.8	520.4	29.2	25,080.7
07/09/76	1.0	24.8	24.8	25,105.5
07/21/76	18.7	559.7	29.9	25,665.2
07/22/76	17.5	395.6	22.6	26,060.8
07/23/76	19.5	626.9	32.1	26,687.7
07/24/76	6.0	186.9	31.1	26,874.6
07/26/76	14.5	524.4	36.2	27,399.0
07/27/76	9.5	297.6	31.3	27,696.6
07/28/76	9.0	228.6	25.4	27,925.2
08/05/76	17.0	512.6	30.2	28,437.8
08/06/76	22.5	684.0	30.4	29,121.8
08/07/76	16.0	487.2	30.4	29,609.0
11/06/76	7.0	186.0	26.6	29,795.0
11/07/76	4.5	113.4	25.2	29,908.4
11/08/76	8.5	236.8	27.9	30,145.2
11/11/76	15.0	404.6	27.0	30,549.8
11/12/76	23.0	606.0	26.3	31,155.8
11/13/76	23.0	575.2	25.0	31,721.0
11/14/76	18.0	430.0	23.9	32,161.0
11/15/76	10.0	283.0	28.3	32,444.0
11/16/76	23.5	665.1	28.3	33,109.9
11/17/76	7.0	196.0	28.0	33,305.9
11/25/76	4.0	92.5	23.1	33,398.4
11/26/76	8.5	251.3	29.6	33,649.7
11/27/76	23.5	748.4	31.8	34,398.1
11/28/76	18.5	542.5	29.3	34,940.6
11/29/76	4.0	116.1	29.0	35,056.7
12/06/76	2.5	76.2	30.5	35,132.9
12/07/76	16.0	446.3	27.9	35,579.2
12/08/76	1.0	30.8	30.8	35,610.0
12/09/76	4.0	109.8	27.4	35,719.8
12/10/76	20.7	460.9	22.3	36,180.7
12/11/76	8.9	211.4	23.8	36,392.1
12/12/76	18.0	548.9	30.5	36,941.0
12/13/76	23.4	714.9	30.6	37,655.9
12/14/76	23.2	687.7	29.6	38,343.6
12/15/76	14.8	440.0	29.7	38,783.6

TABLE B-33. (Continued)

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
12/16/76	11.0	382.8	34.8	39,166.4
12/17/76	13.6	426.4	31.4	39,592.8
12/18/76	16.7	450.9	27.0	40,043.7
12/19/76	16.2	454.5	28.1	40,498.2
12/20/76	17.7	416.4	23.5	40,914.6
12/21/76	15.8	371.0	23.5	41,231.6
12/22/76	20.8	498.3	19.1	41,729.9
12/23/76	11.7	230.4	19.7	41,960.3
01/08/77	11.5	318.4	27.7	42,278.7
01/09/77	21.0	749.3	35.7	43,028.0
01/10/77	9.0	283.0	31.4	43,311.0
01/11/77	23.3	739.4	31.7	44,050.4
01/12/77	1.8	43.5	24.2	44,093.9
01/13/77	12.2	410.1	33.6	44,504.0
01/14/77	10.5	341.2	32.5	44,845.2
01/15/77	9.7	262.2	27.0	45,107.4
01/16/77	0.7	21.8	31.1	45,129.2
01/17/77	8.0	173.3	21.7	45,302.5
01/18/77	19.6	458.1	23.4	45,760.6
01/19/77	12.3	288.5	23.5	46,049.1
01/20/77	13.4	371.0	27.7	45,420.1
01/21/77	7.4	254.9	34.4	46,675.0
01/22/77	9.0	218.6	24.3	46,893.6
01/23/77	23.2	604.2	26.0	47,497.8
01/24/77	11.5	279.4	23.7	47,777.2
01/30/77	4.5	142.4	31.7	47,919.6
01/31/77	21.1	554.3	26.3	48,473.9
02/01/77	17.1	529.8	31.0	49,003.7
02/03/77	6.0	196.0	32.7	49,199.7
02/04/77	24.0	718.5	29.9	49,918.2
02/05/77	19.8	554.3	28.0	50,472.5
02/06/77	22.4	645.9	20.8	51,118.5
02/07/77	3.0	67.1	22.4	51,185.5
02/22/77	13.5	417.3	30.9	51,602.8
02/23/77	14.7	502.5	34.2	52,105.3
02/24/77	23.9	774.7	32.4	52,800.0
02/25/77	23.6	753.0	31.9	53,663.0
02/26/77	18.5	556.1	30.1	54,189.1
02/28/77	16.0	522.5	32.7	54,711.6
03/01/77	23.8	733.8	32.5	55,485.4
03/02/77	21.8	588.8	27.0	56,074.2
03/03/77	14.9	398.3	26.7	56,472.5
03/04/77	11.7	310.3	26.5	56,782.8

TABLE B-33. (Continued)

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
03/05/77	12.0	331.1	27.6	57,113.9
03/06/77	8.0	200.5	25.1	57,314.4
03/07/77	15.3	406.4	26.6	57,720.8
03/08/77	16.2	365.6	22.6	58,086.4
03/09/77	18.2	452.7	24.9	58,539.1
03/10/77	12.6	312.1	24.8	58,851.2
03/11/77	19.7	465.4	23.6	59,316.6
03/12/77	21.8	538.9	24.7	59,855.5
03/13/77	5.5	127.9	23.3	59,983.4
03/14/77	11.6	293.9	25.3	60,277.3
03/15/77	21.7	544.3	25.1	60,821.6
03/16/77	13.2	376.5	28.5	61,198.1
03/17/77	21.6	548.1	25.4	61,746.2
03/18/77	10.7	289.4	27.1	62,035.6
04/25/77	11.0	304.8	27.7	62,340.4
04/26/77	22.3	617.8	27.7	62,958.2
04/27/77	23.3	645.9	27.7	63,604.1
04/28/77	22.2	615.1	27.7	64,219.2
04/29/77	22.8	632.3	27.7	64,851.5
04/30/77	17.5	485.3	27.7	65,336.8
05/02/77	16.3	486.3	29.8	65,823.1
05/03/77	12.0	358.3	29.9	66,181.4
05/04/77	21.8	650.5	29.8	66,831.9
05/05/77	21.3	635.9	29.9	67,467.8
05/06/77	23.5	701.3	29.8	68,169.1
05/07/77	19.5	581.5	29.8	68,750.6
05/09/77	14.5	432.7	29.8	69,183.3
05/10/77	23.5	694.9	29.6	69,878.2
05/11/77	22.5	671.3	29.8	70,549.5
05/12/77	23.0	685.8	29.8	71,235.3
05/13/77	23.0	685.8	29.8	71,921.1
05/14/77	22.5	671.3	29.8	72,592.4
06/20/77	13.3	453.6	34.1	73,046.0
06/21/77	21.8	743.9	34.1	73,789.9
06/22/77	22.5	768.4	34.2	74,558.3
06/24/77	16.0	546.1	34.1	75,104.4
06/25/77	23.0	784.7	34.1	75,889.1
06/29/77	23.0	820.1	35.7	76,709.2
06/30/77	22.0	784.7	35.7	77,493.9
07/01/77	23.0	820.1	35.7	78,314.0
07/02/77	9.5	338.4	35.6	78,652.4
07/11/77	8.0	331.1	41.4	78,983.5
07/12/77	23.0	952.6	41.4	79,936.1

(continued)

TABLE B-33. (Continued)

Date	Operating Time (Hours)	Amount Fired (Mg)	Feed Rate (Mg/hr.)	Cumulative Amount Fired (Mg)
07/13/77	22.0	911.7	41.4	80,847.8
07/14/77	21.5	890.0	41.4	81,737.8
07/15/77	11.0	455.4	41.4	82,193.2
07/23/77	7.5	204.1	27.2	82,397.3
07/24/77	14.0	381.0	27.2	82,778.3
07/26/77	11.0	259.1	23.5	83,165.5
07/27/77	22.0	518.2	23.5	83,683.6
07/28/77	23.5	553.6	23.5	84,237.3
07/29/77	21.0	494.5	23.5	84,731.8
07/30/77	16.0	377.3	23.5	85,109.1
08/01/77	16.0	344.5	21.5	85,453.6
08/02/77	23.0	495.5	21.5	85,949.1
08/03/77	22.5	484.5	21.5	86,433.6
08/04/77	22.5	484.5	21.5	86,918.2
08/05/77	22.5	484.5	21.5	87,402.7
08/18/77	5.0	55.5	11.2	87,458.2
08/19/77	21.5	238.2	11.2	87,696.4
08/20/77	22.0	243.6	11.2	87,940.0
08/22/77	13.0	366.4	28.2	88,306.4
08/23/77	22.0	620.1	28.2	88,926.5
08/24/77	23.0	648.2	28.2	89,574.7
08/25/77	21.5	606.4	28.2	90,181.1
08/26/77	18.0	507.3	28.2	90,688.4
08/27/77	15.0	422.8	28.2	91,111.2
08/29/77	5.0	6.4	1.3	91,117.6
09/06/77	12.5	295.5	23.6	91,413.1
09/07/77	23.0	543.7	23.6	91,956.8
09/08/77	23.0	543.7	23.6	92,500.5
09/09/77	23.0	543.7	23.6	93,044.2
09/10/77	22.0	520.1	23.6	93,564.3
09/12/77	7.5	142.7	19.0	93,707.0
09/14/77	7.0	133.6	19.1	93,840.6
09/15/77	23.0	439.1	19.1	94,279.7
09/16/77	23.0	439.1	19.1	94,718.8
09/17/77	14.0	267.3	19.1	94,986.1
09/19/77	16.0	180.0	11.3	95,166.1
09/20/77	21.0	236.4	11.3	95,402.5
09/21/77	14.0	158.2	11.3	95,560.7

TABLE B-34. DAILY FUEL OIL CONSUMPTION

Date	Consumption (liters)	Refuse fired (Mg)	Standby time (hours)
11/04/76	52,316	0	24.0
11/05/76	92,812	0	24.0
11/06/76	58,842	186	17.0
11/07/76	64,792	113	19.5
11/08/76	55,643	237	15.5
11/09/76	2,971	0	24.0
11/10/76	47,006	0	24.0
11/11/76	23,467	405	9.0
11/12/76	17,116	606	1.0
11/13/76	15,976	575	1.0
11/14/76	55,980	430	6.0
11/15/76	28,690	283	14.0
11/16/76	30,042	665	0.5
11/26/76	45,378	251	15.5
11/27/76	25,647	748	0.5
11/28/76	37,634	543	5.5
11/29/76	46,881	116	20.0
11/30/76	651	0	24.0
12/01/76	1,113	0	24.0
12/06/76	58,864	76	21.5
12/07/76	47,426	446	8.0
12/08/76	16,855	31	23.0
12/09/76	56,722	110	20.0
12/10/76	37,699	461	3.3
12/11/76	56,824	211	15.1
12/12/76	15,132	549	6.0
12/13/76	18,713	715	0.6
12/14/76	23,482	688	0.8
12/15/76	30,772	440	9.2
12/16/76	36,268	383	13.0
12/17/76	24,735	426	10.4
12/18/76	22,854	451	7.3
12/19/76	41,313	455	7.8
12/20/76	28,232	416	6.3
12/21/76	38,111	371	8.2
12/22/76	16,972	498	3.2
01/05/77	49,478	0	24.0
01/08/77	25,821	318	12.5
01/09/77	39,697	749	3.0
01/10/77	38,115	283	15.0
01/13/77	23,107	410	11.8
01/14/77	79,602	341	13.5
01/15/77	55,238	262	14.3
01/16/77	50,992	22	23.3

(continued)

TABLE B-34. (Continued)

Date	Consumption (liters)	Refuse fired (Mg)	Standby time (hours)
01/17/77	55,935	173	16.0
01/18/77	42,774	458	4.4
01/19/77	44,038	288	11.7
01/20/77	25,791	371	10.6
02/04/77	8,766	718	20.0
02/05/77	21,041	554	4.2
02/06/77	30,462	646	1.6
02/07/77	61,699	67	21.0
02/08/77	753	0	24.0
02/20/77	53,925	0	24.0
02/21/77	72,630	0	24.0
02/22/77	24,383	417	10.5
02/25/77	6,836	753	0.4
03/02/77	15,704	589	2.2
03/03/77	37,960	398	9.1
02/07/77	20,814	406	8.7
03/08/77	27,350	366	7.8
03/09/77	22,415	453	5.8
03/10/77	57,354	312	11.4
03/11/77	6,938	465	4.3
03/12/77	20,061	539	2.2
03/13/77	75,628	128	18.5
03/14/77	28,660	294	12.4
03/15/77	21,366	544	2.3
03/16/77	33,967	376	10.8
03/17/77	14,160	548	2.4
03/18/77	57,577	289	13.3
03/19/77	8,463	0	24.0
04/25/77	32,460	305	13.0
04/26/77	15,363	618	1.7
04/27/77	16,877	646	0.7
04/28/77	15,492	615	1.8
04/29/77	29,667	632	1.2
04/30/77	36,631	485	6.5
05/01/77	50,575	0	24.0
05/02/77	25,927	486	7.7
05/05/77	27,347	636	2.7
05/06/77	22,842	701	0.5
05/07/77	45,647	581	4.5
05/08/77	61,101	0	24.0
05/09/77	20,325	433	9.5
05/10/77	17,191	695	0.5
05/12/77	17,407	686	1.0

TABLE B-35. STANDBY HOURLY FUEL OIL CONSUMPTION

Date	Time Period	Consumption (l/hr)
11/07/76	700 - 1200	3592
11/15/76	700 - 900	2672
11/15/76	900 - 1200	3235
11/17/76	1200 - 1300	3388
11/17/76	1300 - 1500	3242
11/29/76	1300 - 1400	3270
11/29/76	1400 - 1500	4129
11/29/76	1500 - 1600	2926
11/29/76	1600 - 1700	3611
12/07/76	700 - 1000	3316
12/07/76	1100 - 1200	3637
12/15/76	1000 - 1100	3837
12/15/76	1100 - 1200	3671
12/15/76	1200 - 1300	3804
12/17/76	1300 - 1400	3081
12/17/76	1400 - 1500	3115
12/19/76	1100 - 1200	3069
01/19/77	800 - 900	3512
01/19/77	900 - 1000	3796
01/19/77	1000 - 1100	4027
01/21/77	1300 - 1400	3743
01/21/77	1400 - 1500	3815
01/24/77	1200 - 2400	3603
01/25/77	000 - 700	3603
03/09/77	700 - 1000	3112
03/09/77	1000 - 1100	3085
03/10/77	1200 - 1300	3388
03/10/77	1300 - 1400	3429
Weighted average		3466

TABLE B-36. OPERATING HOURLY FUEL OIL CONSUMPTION

Date	Time Period	Feed Rate (Mg/hr)	Consumption (l/hr)
11/12/76	800 - 900	23.25	738
11/12/76	900 - 1300	28.12	728
11/12/76	1300 - 2400	29.71	749
11/13/76	000 - 700	29.71	749
11/13/76	700 - 1400	23.74	727
11/15/76	1500 - 1700	29.04	770
11/15/76	1700 - 1800	27.51	738
11/15/76	1800 - 2400	29.24	735
11/15/76	000 - 900	29.24	735
11/16/76	900 - 1600	30.76	735
11/16/76	1700 - 1800	25.00	738
11/29/76	1100 - 1200	34.12	787
12/07/76	1400 - 1500	33.26	753
12/07/76	1500 - 1700	32.83	687
12/07/76	1700 - 1800	32.53	734
12/12/76	1100 - 1300	31.00	672
12/13/76	1300 - 1400	36.33	780
12/13/76	1400 - 1500	30.68	746
12/13/76	1500 - 1600	41.17	708
12/13/76	1600 - 1700	31.58	681
12/13/76	1700 - 1800	30.65	693
12/13/76	1900 - 2400	---	716
12/14/76	000 - 700	---	716
12/14/76	1000 - 1100	31.21	730
12/14/76	1300 - 1600	31.88	766
12/14/76	1600 - 1700	31.69	825
12/14/76	1700 - 1800	34.13	746
12/16/76	700 - 1000	35.76	482
12/16/76	1000 - 1100	37.38	462
12/17/76	1000 - 1100	37.38	526
12/18/76	1200 - 1300	---	352
12/18/76	1300 - 1400	34.38	363
12/18/76	1600 - 1700	26.20	322
12/21/76	800 - 900	21.83	333
12/21/76	900 - 1000	22.09	397
12/21/76	1000 - 1100	27.81	360
01/13/77	1500 - 1600	---	357
01/13/77	1600 - 1700	34.31	269
01/13/77	1700 - 1800	36.63	265
01/18/77	1000 - 1100	30.92	291
01/18/77	1100 - 1300	31.94	308
01/18/77	1300 - 1400	34.88	326
01/18/77	1400 - 1500	34.57	299
01/18/77	1500 - 1600	26.83	295

(continued)

TABLE B-36. (Continued)

Date	Time Period	Feed Rate (Mg/hr)	Consumption (l/hr)
01/18/77	1600 - 1700	26.83	291
01/20/77	1200 - 1300	34.27	344
01/20/77	1300 - 1400	34.79	329
01/20/77	1400 - 1500	40.26	314
01/23/77	1100 - 1200	23.77	291
01/24/77	900 - 1000	22.81	227
01/31/77	900 - 1000	28.61	280
01/31/77	1500 - 1600	---	265
01/31/77	1600 - 1700	---	276
02/01/77	800 - 900	24.31	303
02/01/77	900 - 1000	30.62	269
02/01/77	1000 - 1100	37.33	299
02/01/77	1100 - 1200	33.16	280
02/01/77	1200 - 1300	30.25	276
02/01/77	1300 - 1400	35.72	291
02/01/77	1400 - 1500	28.80	257
02/03/77	1700 - 1800	32.00	261
02/03/77	2100 - 2200	44.13	254
02/03/77	2200 - 2300	31.27	261
02/03/77	2300 - 2400	34.52	278
02/04/77	000 - 700	34.52	278
02/04/77	700 - 1000	29.60	227
02/04/77	1000 - 1100	28.66	269
02/04/77	1100 - 1200	20.41	280
02/04/77	1200 - 1400	26.52	257
02/04/77	1400 - 1500	29.02	265
02/05/77	1400 - 1500	22.57	284
02/05/77	1500 - 1600	29.79	291
02/05/77	1600 - 1700	34.98	257
02/22/77	1100 - 1200	33.40	265
02/22/77	1200 - 1300	32.76	265
02/22/77	1300 - 1500	35.43	260
02/25/77	700 - 800	39.73	307
02/25/77	800 - 900	34.32	223
02/25/77	900 - 1000	37.19	242
02/25/77	1000 - 1100	38.18	295
02/25/77	1100 - 1200	37.81	216
02/25/77	1200 - 1300	31.97	288
02/25/77	1300 - 1400	33.80	246
02/28/77	1000 - 1100	33.97	291
02/28/77	1100 - 1200	39.26	303
02/28/77	1200 - 1400	36.81	259
02/28/77	1400 - 1500	34.31	250
02/28/77	1500 - 1600	45.61	303

(continued)

TABLE B-36. (Continued)

Date	Time Period	Feed Rate (Mg/hr)	Consumption (l/hr)
02/28/77	1600 - 1700	31.54	307
02/28/77	1700 - 1800	38.96	231
03/10/77	700 - 1000	29.09	233
03/10/77	1000 - 1100	26.99	235
03/11/77	700 - 800	28.92	246
03/11/77	800 - 900	24.30	197
03/11/77	900 - 1000	26.20	227
03/11/77	1000 - 1100	28.60	227
03/11/77	1100 - 1400	29.60	178
03/11/77	1400 - 1500	29.60	144
03/15/77	1500 - 1600	35.67	318
03/15/77	1600 - 1700	20.92	394
03/15/77	1700 - 1800	28.56	326
03/15/77	1800 - 1900	26.79	284
03/15/77	1900 - 2000	29.55	231
03/15/77	2100 - 2200	26.29	341
03/15/77	2200 - 2300	32.24	352
03/17/77	1600 - 1700	26.12	689
04/27/77	1500 - 1600	18.75	731
04/27/77	1600 - 1700	39.15	496
04/29/77	1500 - 1600	---	579
04/29/77	1700 - 1800	21.43	556
04/29/77	1800 - 1900	41.03	553
04/29/77	1900 - 2000	22.28	492
04/29/77	2000 - 2100	26.71	606
05/09/77	1200 - 1300	---	708
05/09/77	1700 - 1800	39.87	617
05/09/77	1800 - 1900	33.50	640
05/13/77	1100 - 1200	30.58	897
05/13/77	1200 - 1300	33.74	749

TABLE B-37. ANALYSIS OF NO. 2 FUEL OIL

Date		8/5/76*	4/29/77
Time		1400	1530
Ash	(%)	.00	.00
Sulfur	(%)	.22	.30
Heat content	(MJ/kg)	45.3	45.8
Carbon	(%)	83.65	85.91
Hydrogen	(%)	12.09	13.75
Nitrogen	(%)	.002	.03
Oxygen	(%)	4.04	.01

* Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250 St. Louis, Missouri, 1976. Table 3A.

Burner Fuel Flow

No direct measurement of fuel oil flow to any individual burner nozzle is available. Hence, the only possible fuel oil flow measurements are made at the flow meter supplying the two main kiln burners and the totalizing meter, discussed previously, which supplies the fuel oil for all the burners. The meter registering the fuel oil flow to the two main kiln burners has an indicator on the main control panel. Since the kiln standby and heat-up burner is off during normal operation the flow of the on-stream lead burner is determined by reading the indicator on the control panel. This data is recorded hourly by city personnel. The four kiln safety burners are identical and each has a fixed firing rate of 0.032 l/min. The burners are on at all times from heat-up to shutdown.

The gas purifier pilot burner has a fixed firing rate of 0.63 l/min. The gas purifier standby burner has a variable firing rate with a maximum fuel oil firing rate of 70.0 l/min. This burner is off during normal operation and its fuel oil flow rate can be determined by subtracting the sum of the other burner flows from the total. The fuel oil burner in the slag tap hole also has a fixed firing rate.

The main purpose of known individual burner firing rates is to determine the fuel oil flow rates to the kiln and the gas purifier for balance purposes. The kiln fuel oil flow rate is therefore the sum of the reading on the control room indicator and the flow to the four safety burners. The flow rate to the gas purifier is the difference between the total fuel oil consumption and the kiln fuel oil consumption.

Energy input calculations are made by converting the mass flow rate to energy flow rate by multiplying the mass flow rate by the average higher heating value of the No. 2 fuel oil (Table B-37), the density of the fuel oil (assumed from standard tables to be .892 kg/l), and assuming a .985 combustion efficiency.

Propane Consumption

The propane consumption was discussed in detail in Volume II, and the propane consumption data is shown in Table B-38.

COMBUSTION AIR FLOW RATES

Combustion air enters the thermal processing vessels by three methods. Some combustion air is blown into the kiln and gas purifier by six combustion air fans. Additional air enters the gas purifier exit duct through the quench air openings due to subatmospheric pressure within the duct. Finally unmeasurable amounts of leakage air enter the thermal processing vessels due to their internal subatmospheric pressure, through the kiln seals, ram feeders, and through the boiler shell.

TABLE B-38. PROPANE CONSUMPTION†

Date	Time	Propane Used (L)	No. of Burners	Propane Rate (L/Hr)
12/08/76	1200	91	0	2
12/15/76	1030	318	0	2
12/15/76	1300	420	1	170
12/16/76	0830	3407	1	174
12/16/76	1030	473	1	238
12/16/76	1415	750	1	201
12/17/76	0830	3312	1	182
12/23/76	0840	1230	1	76
12/23/76	1430	265	1	45

† Unpublished Monsanto data.

Combustion Air Fans

The process air flow delivered by the five combustion air fans was determined for the mass balance by either direct fan inlet velocity measurement or fan inlet damper correlation curves. Air flow velocity at the inlet was determined using a hand-held, totalizing, vane anemometer in each of the fan inlets. The anemometer was held in a series of eight positions for fifteen seconds at each position. Four of the positions were equal area points along a vertical radial line and the other four points were on a horizontal radial line. The anemometer totalizer was turned off for fifteen seconds between points to allow for velocity stabilization of the anemometer at each point. The reading on the totalizer was divided by the time (2 minutes) to calculate the indicated average velocity. The actual velocity was determined from the indicated velocity by using the calibration curve shown in Figure B-3 which was developed from a calibration chart supplied by the manufacturer.

The volumetric flow rate was determined from the velocity measurements by using the area of the fan inlet. The inlet areas for each of the fans are as follows:

<u>Fan</u>	<u>Area (m²)</u>
Refuse combustion air fan	0.94
Kiln combustion air fan (turbine)	0.67
Kiln combustion air fan (motor)	0.67
Gas purifier combustion air fan	0.94
Crossover combustion air fan	2.16

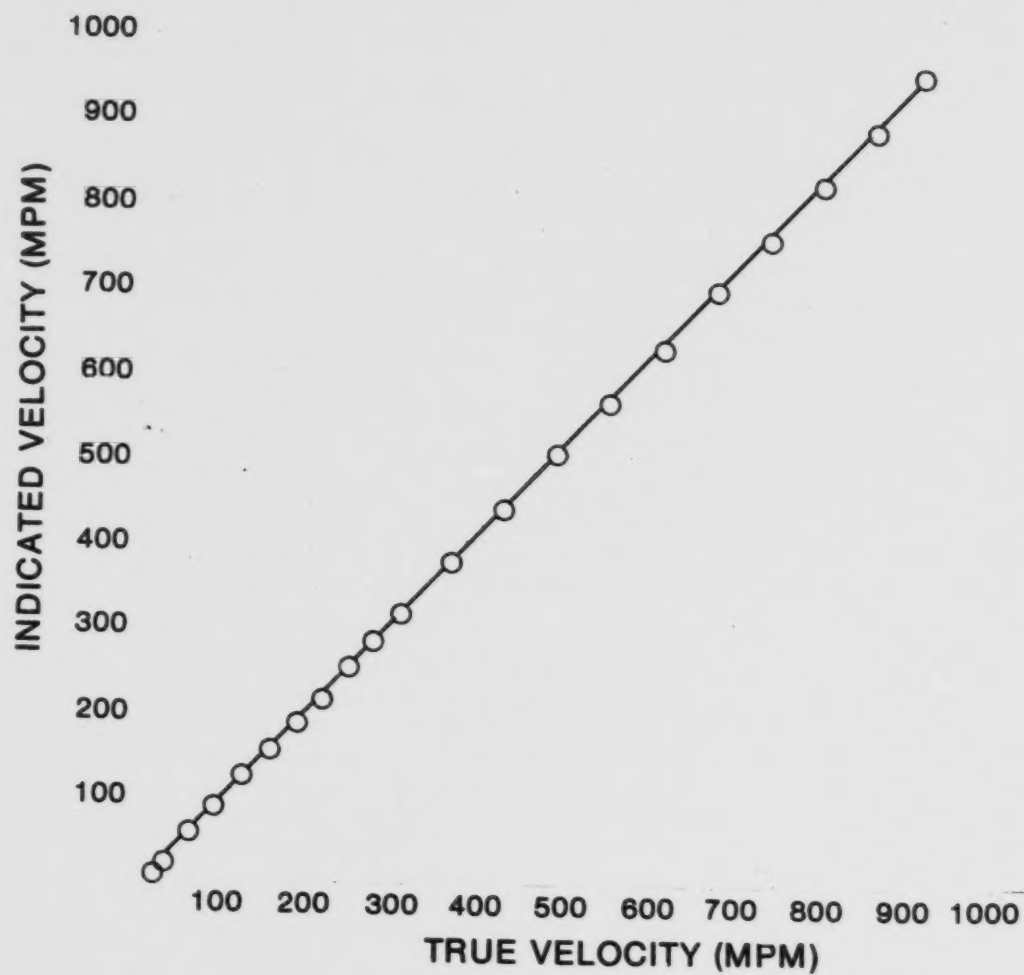


Figure B-3. Anemometer calibration curve.

The field fan curves for each of these fans are shown in Figures B-4 through B-8. These figures also include the results of Monsanto fan curve tests during a shutdown period and Monsanto field fan curve tests.

In order to calculate the mass flow rate using the volumetric flow rate the density of the air must be known. Ambient air density, ρ_a , was calculated from the ambient temperature, pressure, and relative humidity as follows. Using the relative humidity and ambient temperatures (dry bulb) the ASHRAE psychrometric charts (either No. 1 or No. 2 depending upon ambient temperature) are entered and a humidity ratio, ω , is determined which has the units of mass of water vapor per unit mass of dry air. From the equation

$$\rho_a = \frac{PB (1 + \omega)}{(1 + 1.61 \omega) RT}$$

ambient air density can be is barometric pressure. R is the gas constant, and T is the absolute temperature. The mass flow rate for each fan was calculated by multiplying the air density by the volumetric flow rate.

Often field damper settings and inlet velocity measurements were not available for balance calculations. The control room indicator which displayed damper position was recorded hourly by the city. In order to use this data fan curves were plotted for both field and control room damper settings. These fan curves are shown in Figures B-9 through B-15. The gas purifier and crossover combustion air fans are frequently off during refuse processing and air is drawn through the fan inlets by the subatmospheric pressures existing within the process vessels. As a result of this induced flow, with no indicated control variation, the air flow can be observed to shift radically. Naturally the control variable in these cases is process pressure which does not appear in the curves, nor is there sufficient data to develop an inlet flow map which would also correlate process pressure.

The dust collection fan discharges into the crossover duct providing a portion of the process combustion air. Its use as a dust collection device dictates that the fan can be operated at a constant volume flow. The volumetric flow rate of the fan discharge (Table B-39) was determined by measuring the velocity of the air in the discharge duct which has a known cross sectional area. The velocity was measured using a standard pitot tube and horizontal manometer. This method is discussed in detail later. This air density was determined by the method discussed previously.

Mass flow through the fan varies only with the ambient air density. Multiplying the volume flow rate by the ambient density derived as previously described yields the fan mass flow rate.

Quench Air Flow

The air flow through the quench air openings and dampers, previously described in Volume II, is dependent upon the cross-sectional area of the opening in the duct and the pressure differential between the duct and the atmosphere. Figure B-16 shows the ideal (calculated) air flow into the duct through the slotted quench air damper opening under various differential

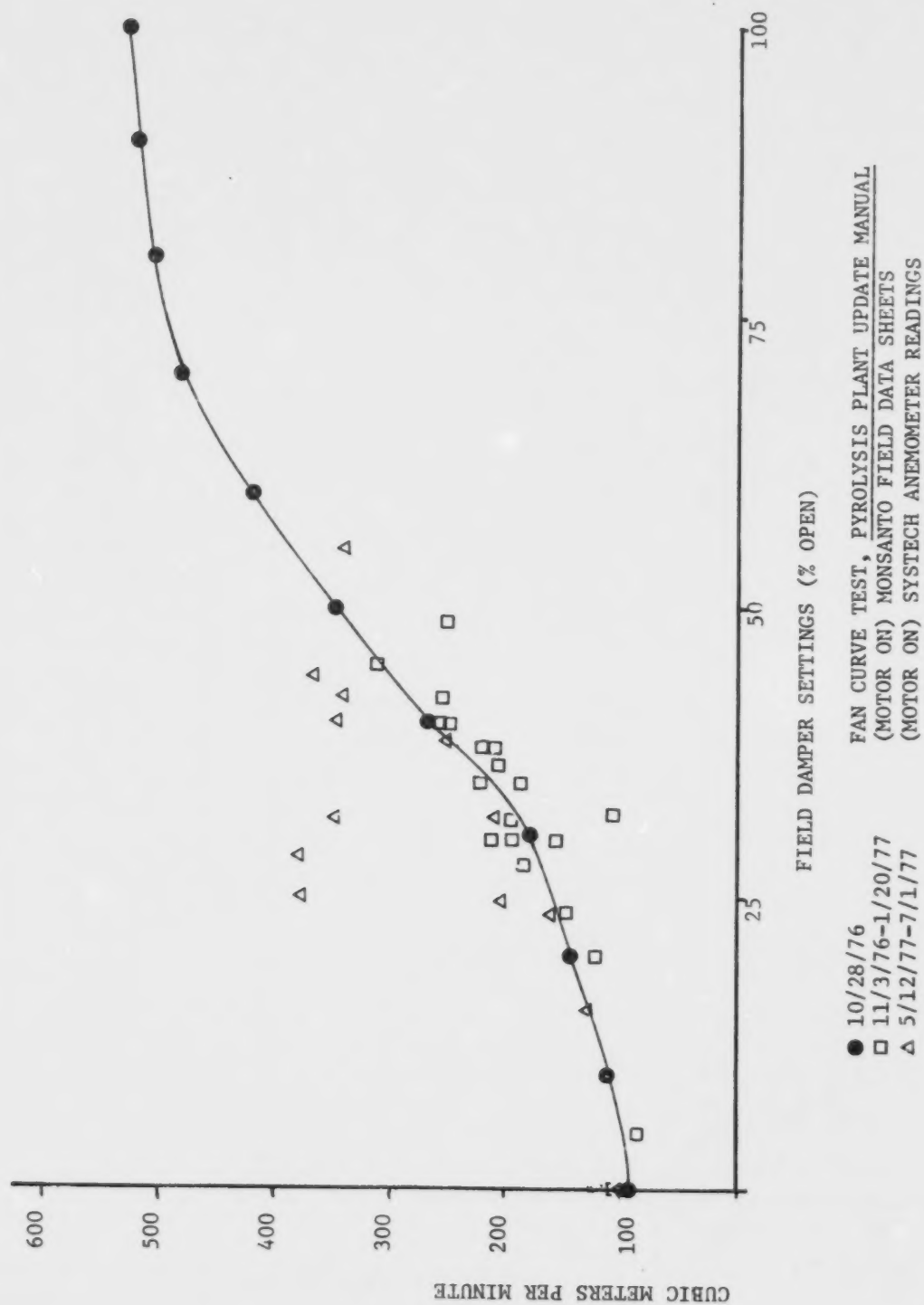
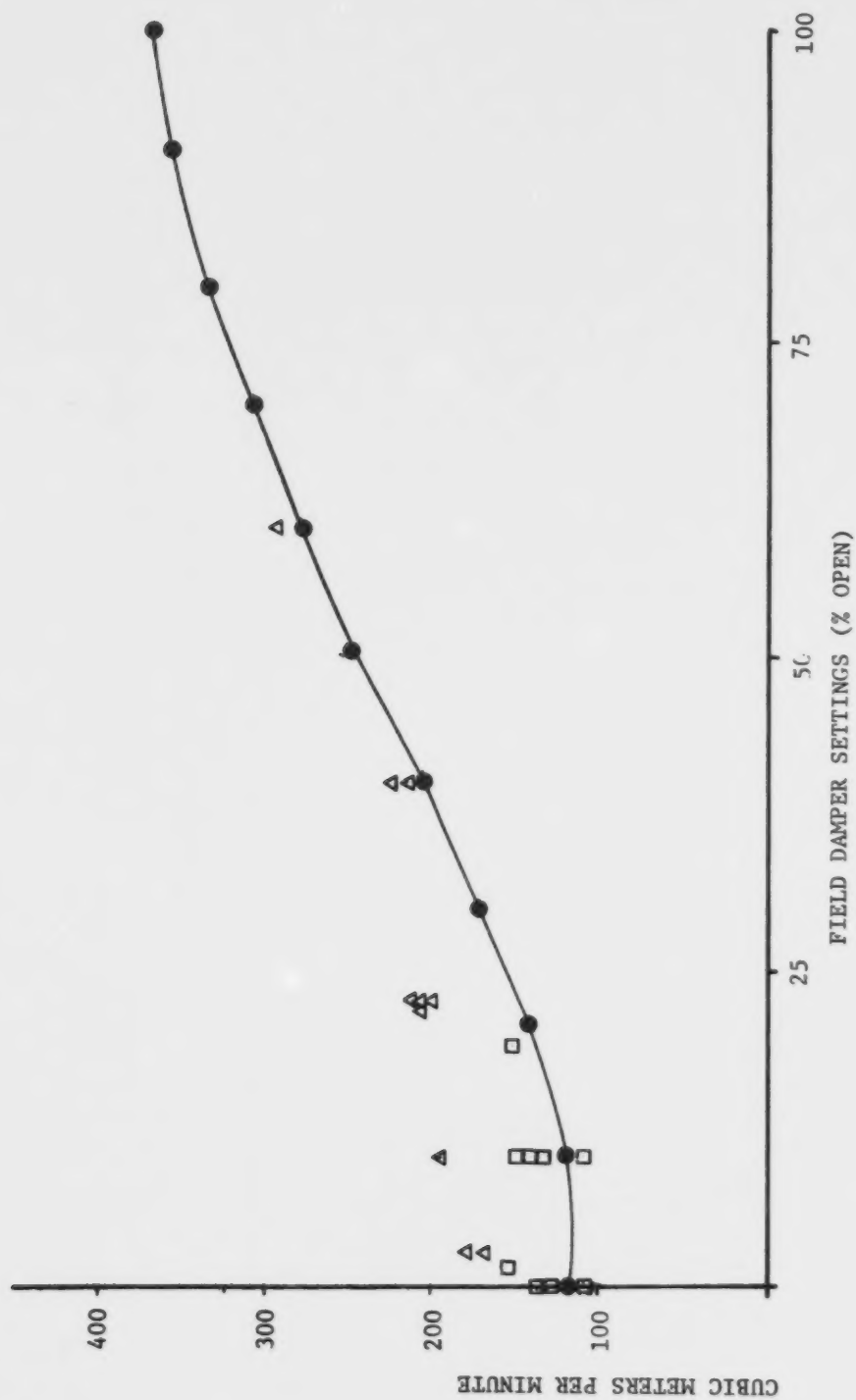


Figure B-4. Refuse combustion air fan field fan curve.



● 10/28/76 FAN CURVE TEST, PYROLYSIS PLANT UPDATE MANUAL
 □ 11/3/76-1/20/77 (MOTOR ON) MONSANTO FIELD DATA SHEETS
 Δ 5/12/77-7/1/77 (MOTOR ON) SYSTECH ANEMOMETER READINGS

Figure B-5. Turbine driven kiln combustion air fan field fan curve.

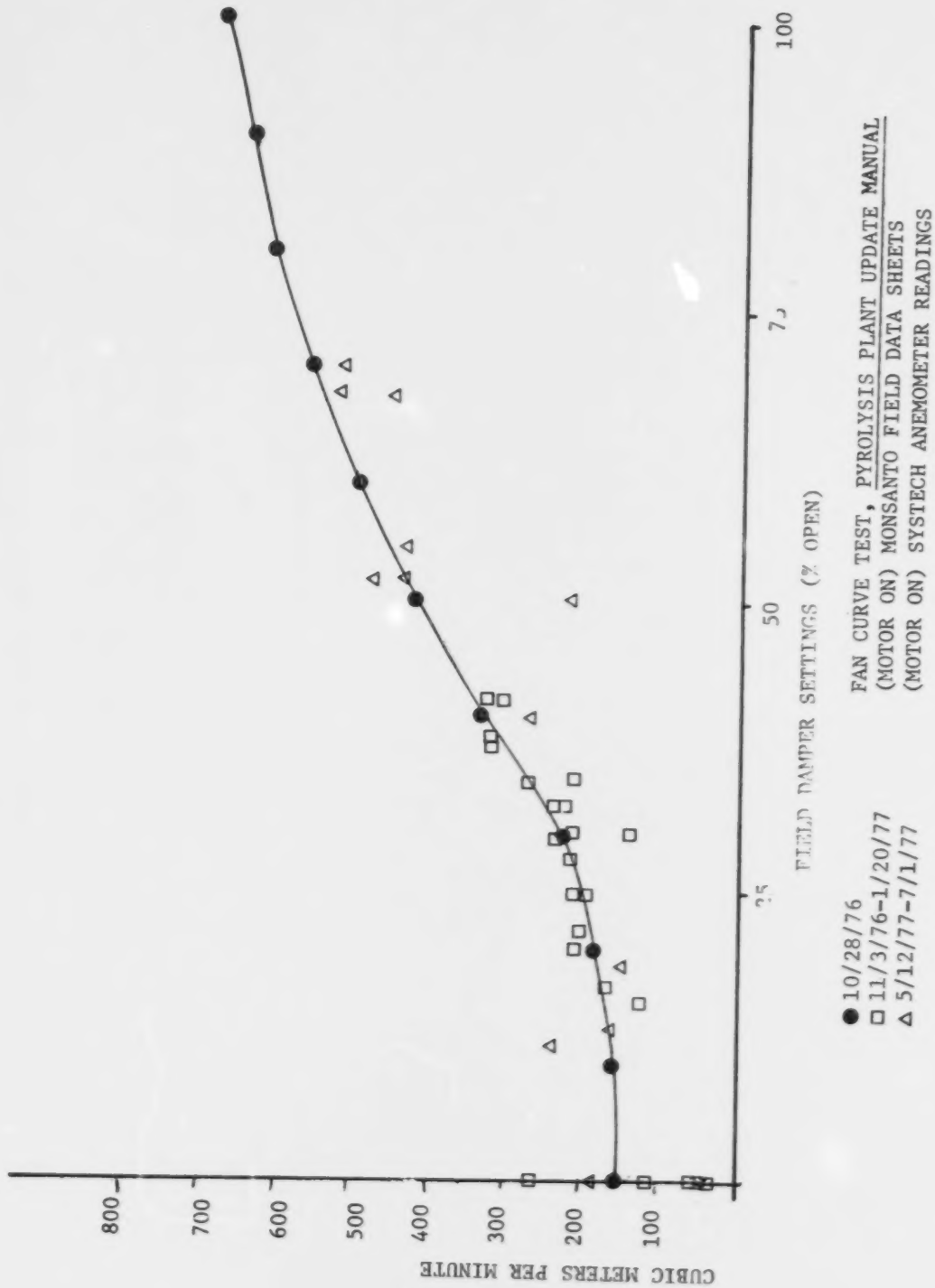
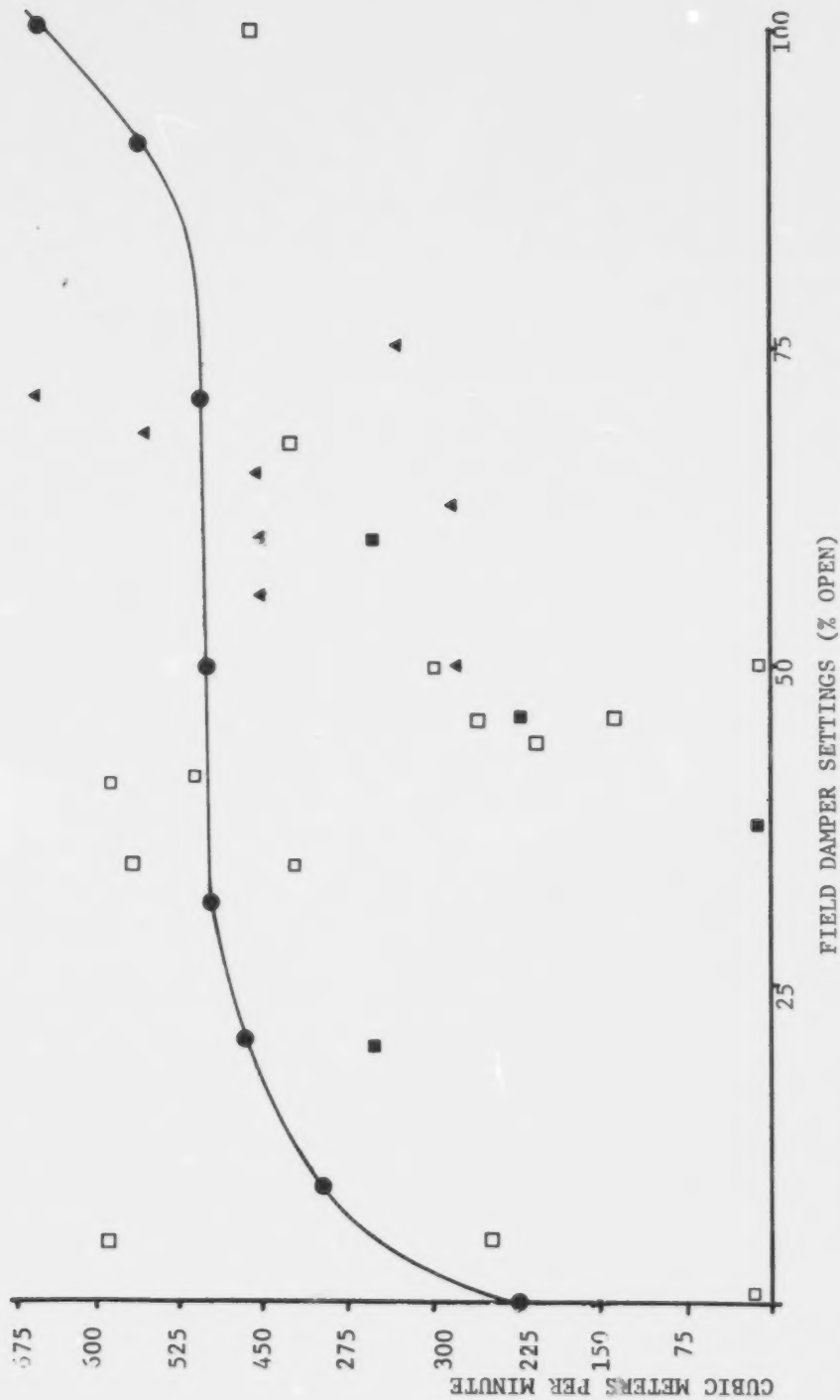


Figure B-6. Motor driven kiln combustion air fan field fan curve.



● 5/2/76
 □ 11/3/76-1/20/77
 ■ 11/3/76-1/20/77
 △ 5/12/77-7/1/77
 ▲ 5/12/77-7/1/77

FAN CURVE TEST, PYROLYSIS PLANT UPDATE MANUAL
 (MOTOR ON) MONSANTO FIELD DATA SHEETS
 (MOTOR OFF) MONSANTO FIELD DATA SHEETS
 (MOTOR ON) SYSTECH ANEMOMETER READINGS
 (MOTOR OFF) SYSTECH ANEMOMETER READINGS

Figure B-8. Crossover combustion air fan field fan curve.

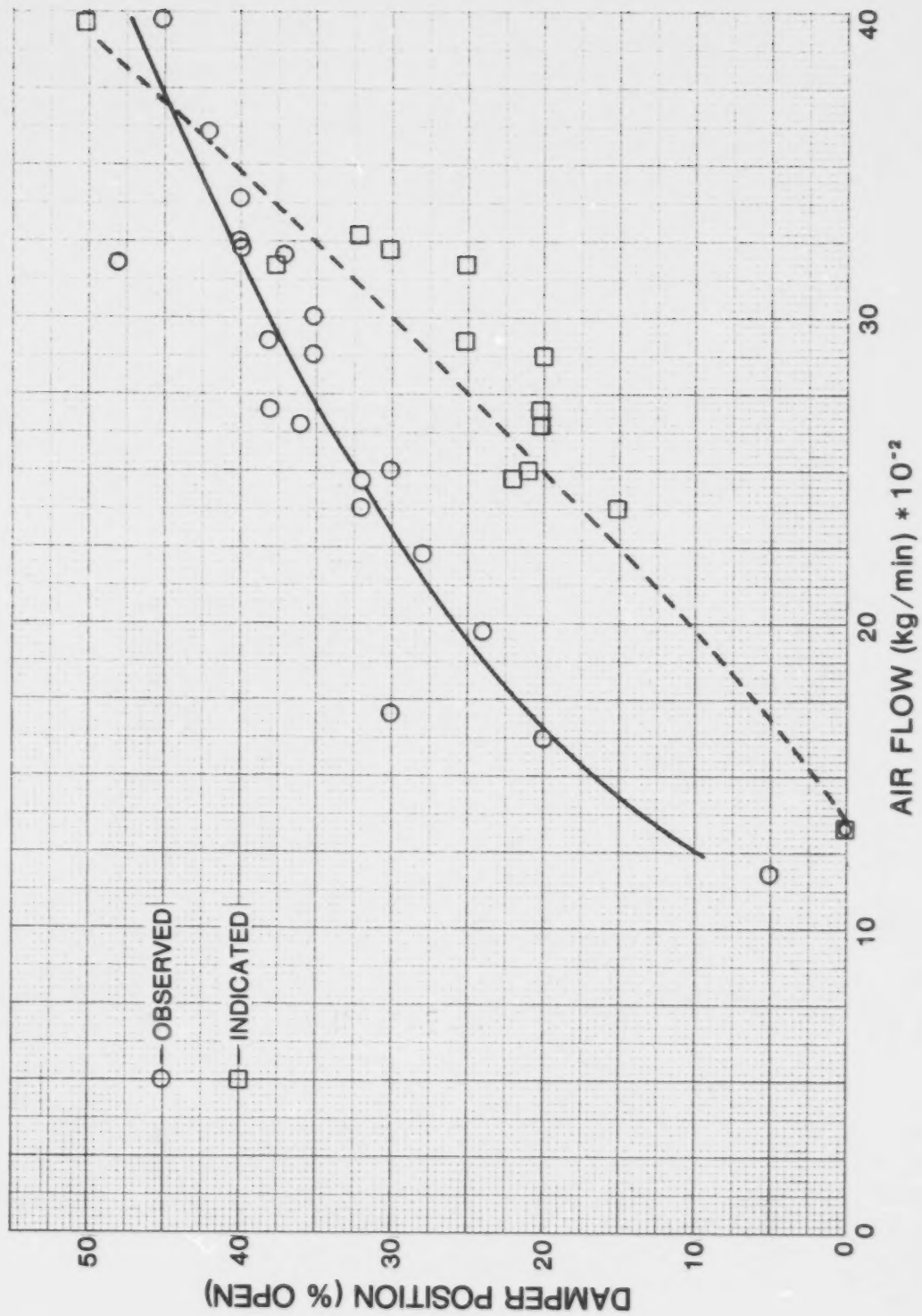


Figure B-9. Refuse combustion air fan curves.

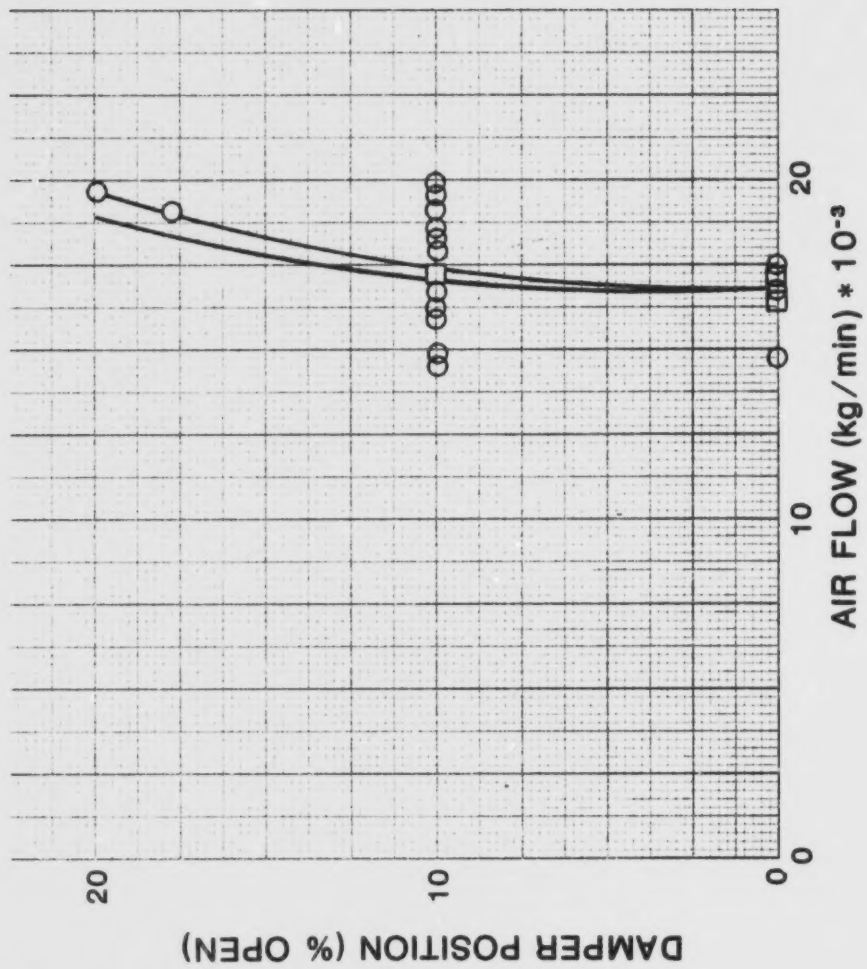


Figure B-10. Turbine driven kiln combustion air fan curves.

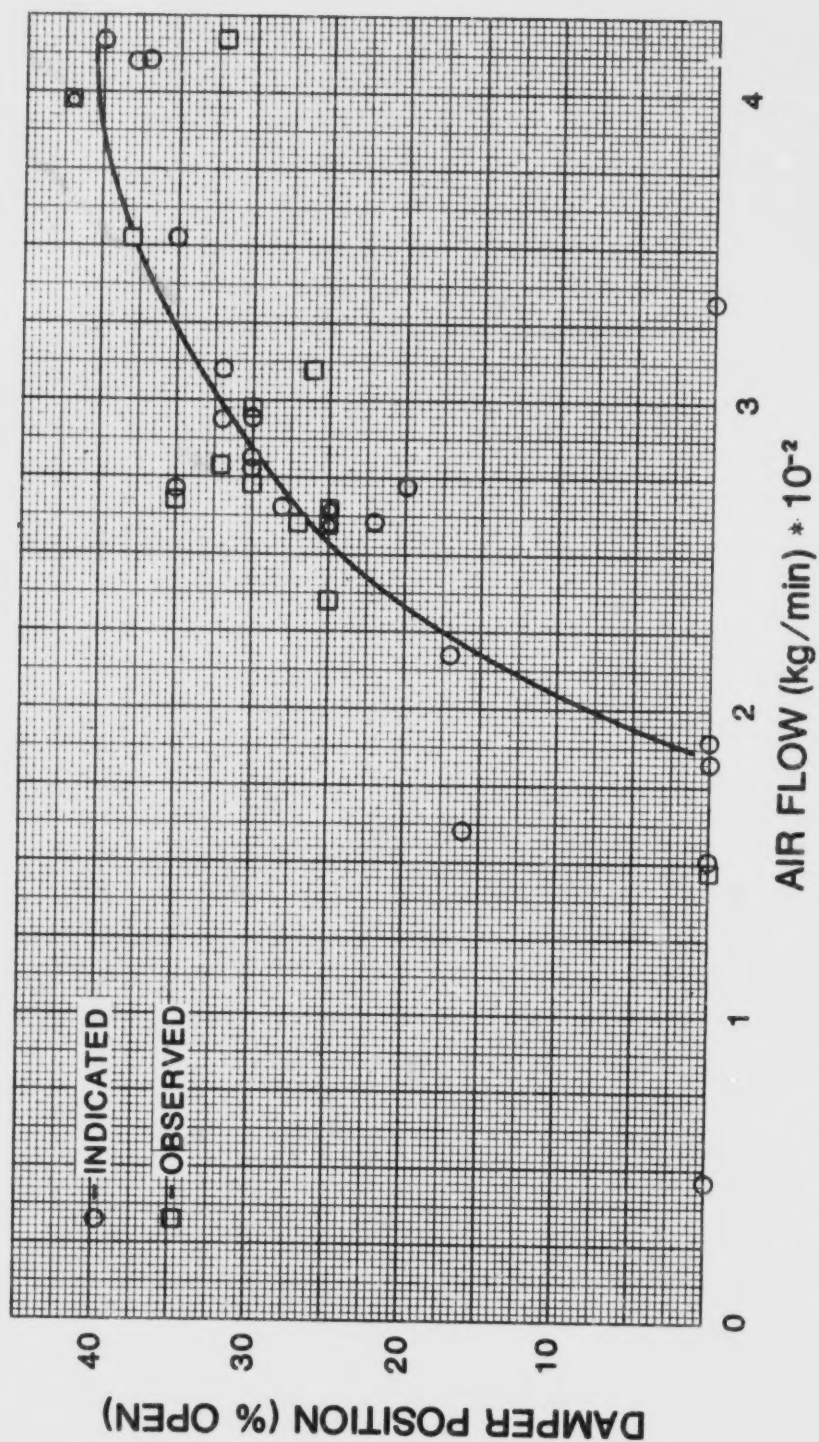


Figure B-11. Motor-driven kiln combustion air fan curve.

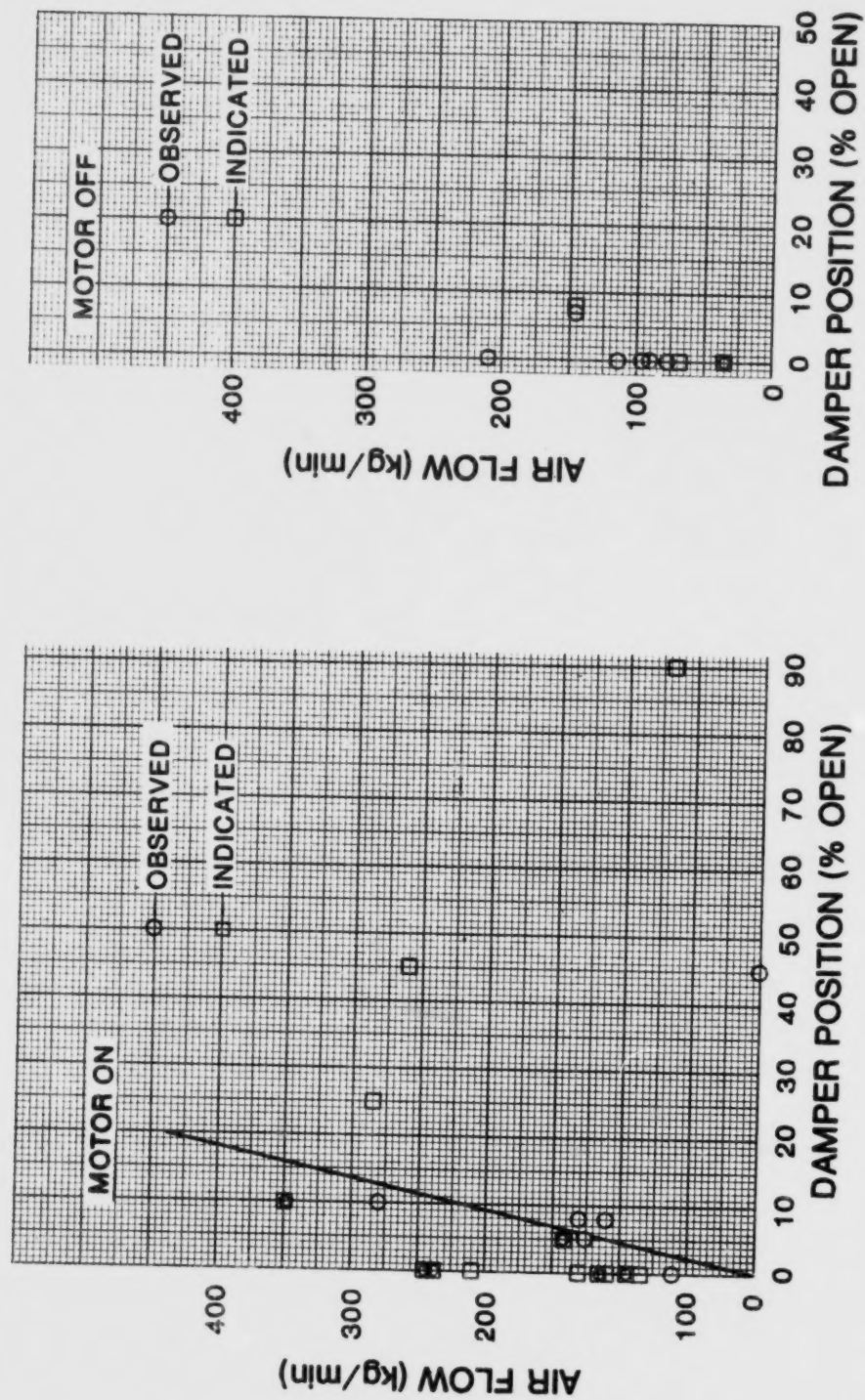


Figure B-12. Gas purifier combustion air fan curve.

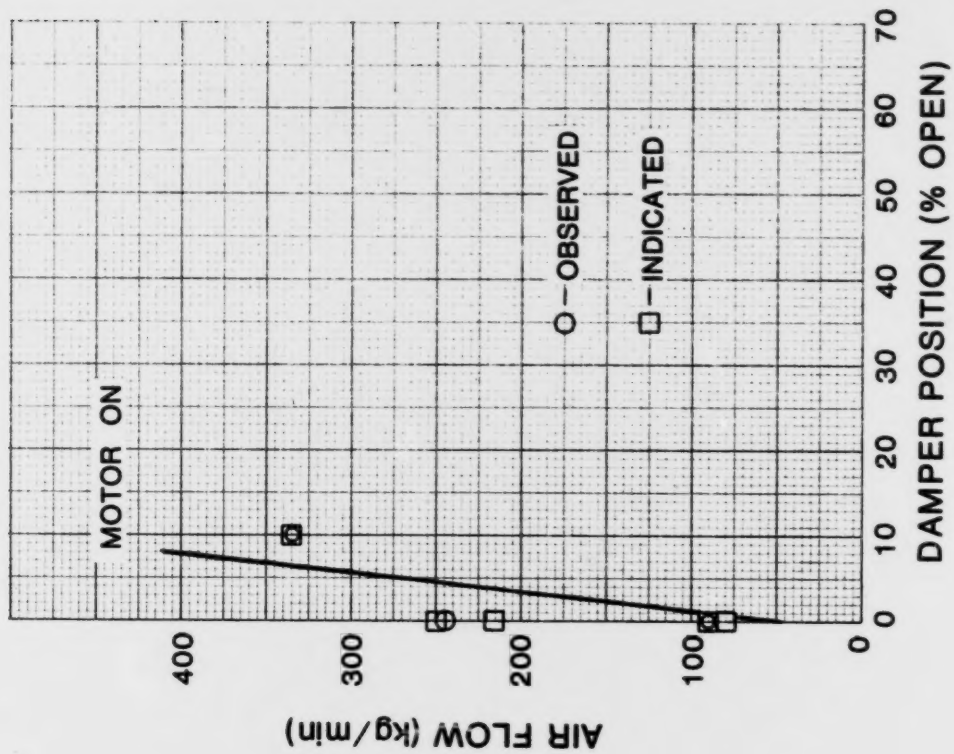


Figure B-13. Gas purifier combustion air fan curves.

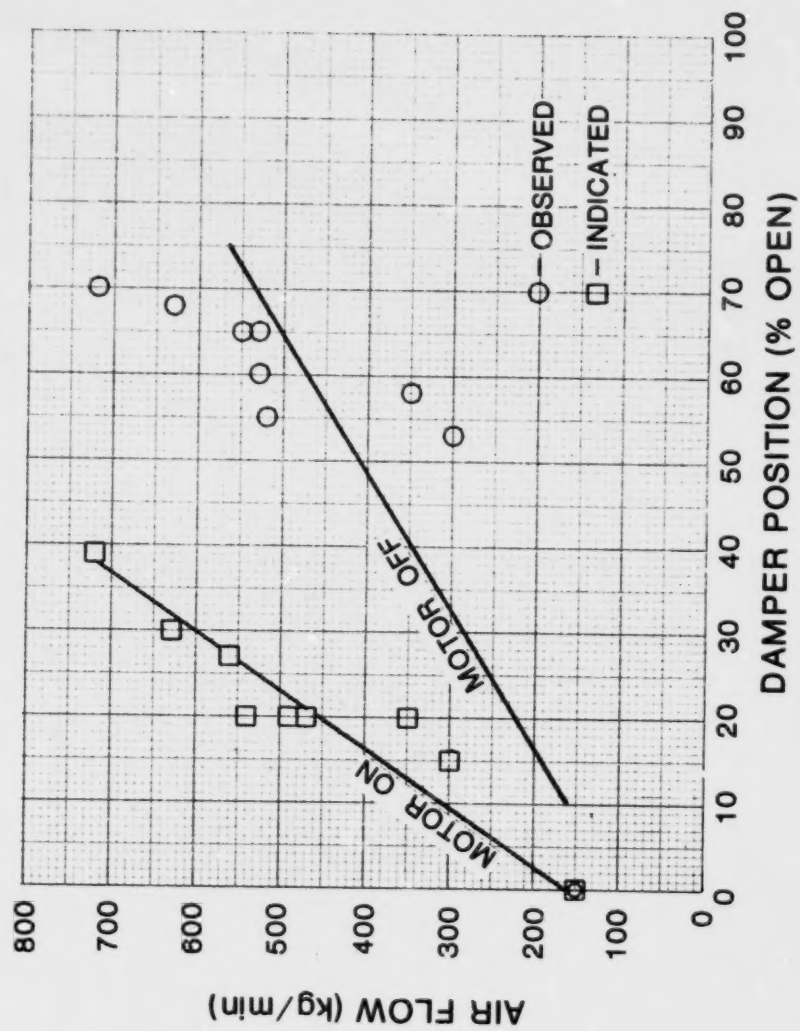


Figure B-14. Crossover combustion air fan curves.

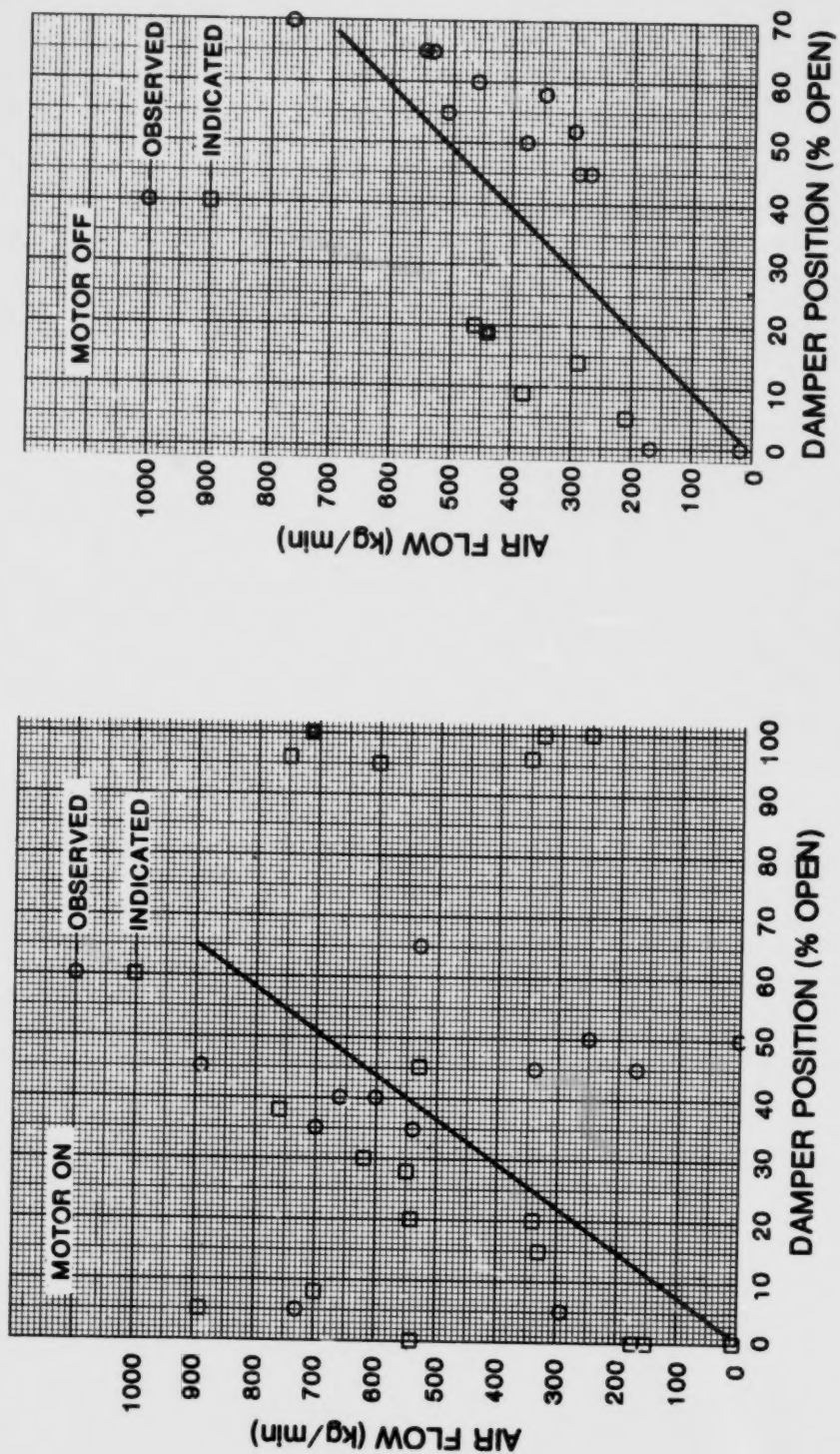


Figure B-15. Crossover combustion air fan curve.

TABLE B-39. C18 FAN FLOW MEASUREMENTS

DATE	TIME	SLIDE A POSITION	SLIDE B POSITION	FAN INLET FLOW (m ³ /min.)	FAN OUTLET FLOW (m ³ /min.)	POINT A FLOW (m ³ /min.)	POINT B FLOW (m ³ /min.)
10/25/76*	1500	OPEN	OPEN	353		196	254
10/25/76*	1500	OPEN	CLOSED	353		315	
10/26/76*	1500	OPEN	CLOSED	365		311	
10/27/76*	0930	OPEN	OPEN	365	365	195	
10/27/76*	0930	IN 7.6cm	OPEN	365		190	
10/27/76*	0930	IN 15cm	OPEN	365		204	
10/27/76*	0930	IN 22cm	OPEN	365		201	
5/14/77	1400	OPEN	OPEN		259		

*Monsanto Field Data (not published).

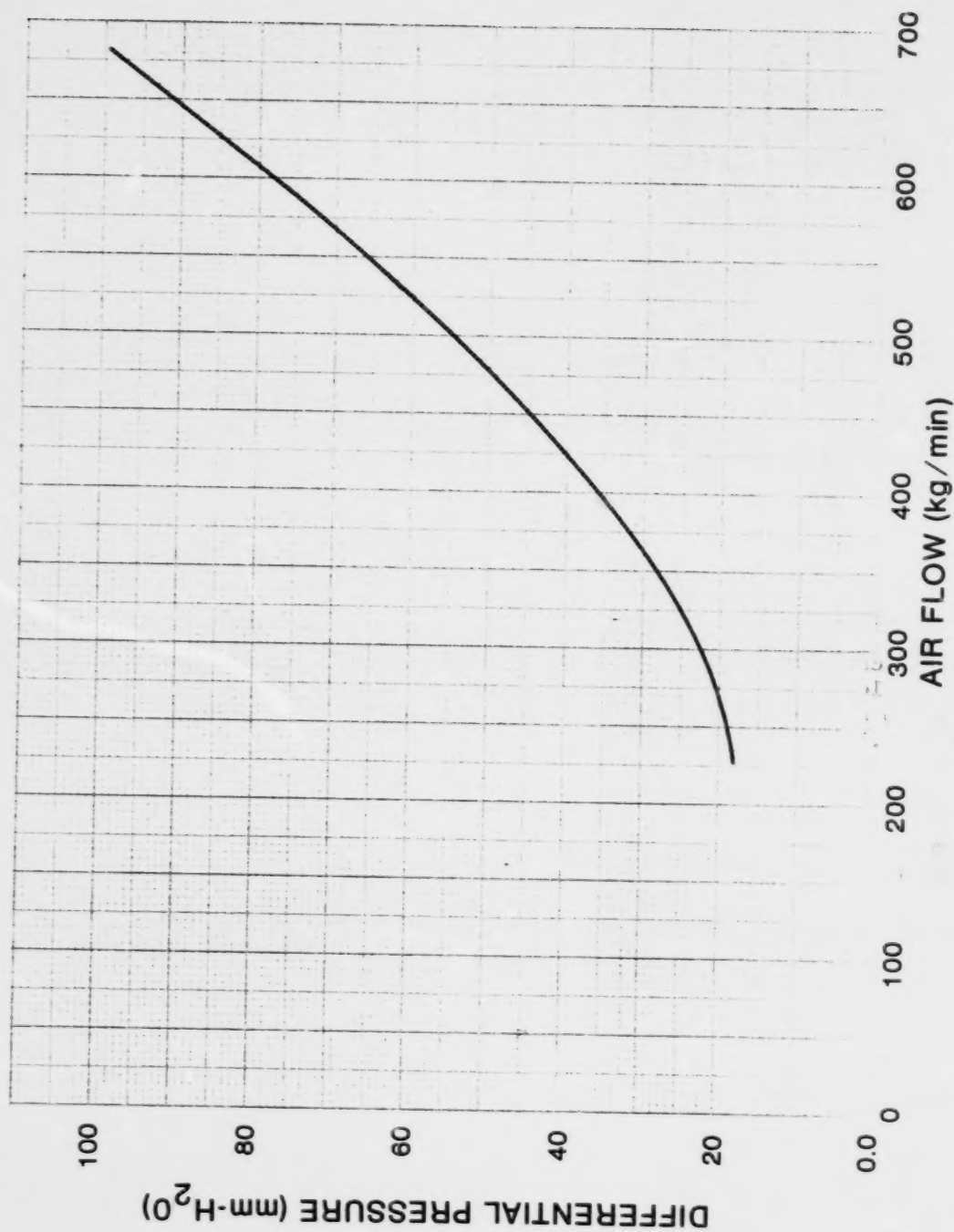


Figure B-16. Flow through slotted quench damper (100% open).

pressures. Only the 100 percent open damper position is shown because it is stuck at this position. From this curve the air flow through this opening can be determined based on the estimated differential pressure.

The butterfly valve damper opening is the same size as the slotted damper opening and when the butterfly valve is open full the flow is the same as the slotted damper opening. When the butterfly valve is fully closed, there is still an open area of 0.056 m^2 (0.6 ft.^2) resulting in some air flow. Figure B-17 shows the calculated air flow curves for 0, 20, 40, 60, 80, and 100 percent open areas for the butterfly valve damper opening. The percentage open is recorded hourly by the city and can be read easily in the field.

Leakage Air Flow

The leakage air through the ram snouts, kiln seals, and boiler shell was determined using two test points when all the major inputs to the system were known except for the leakage air. During the standby test of June 28, 1977 at 1530 hours and the on-stream test of July 1, 1977 at 0900 hours, the refuse in the ram snouts did not provide a good seal. As a result, the kiln mass balance could not be determined by measuring and summing the known inputs and outputs. By determining the total system input flows, and subtracting them and the residue and slag outputs from the flow at the boiler discharge, the leakage air was determined. The leakage rate during the standby test was 156.5 kg/min. (344.3 lbs./min.) and 113.4 kg/min. (249.5 lbs./min.) during the on-stream measured refuse test.

Verification of this leakage air rate was made by calculating the necessary flow area required to pass those quantities of air. The flow area required to accommodate the standby leakage rate, assuming a flow coefficient of 0.6 is 0.1 m^2 (1.1 ft.^2). This magnitude of area when split between the two ram tubes is considered to be a reasonable value since it indicates an average gap between the waste plug and the ram walls of slightly more than 1 cm (0.4 in.). Naturally there was not a uniform gap between the refuse and the ram snout, but the magnitude of the dimension is reasonable. A similar check of the on-stream test indicated a leakage area of approximately half that estimated for the standby test.

During subsequent tests, the refuse feed rate was estimated, introducing a margin of error into the balance calculation which precluded a determination of the leakage air flow. Since there was no means of estimating the leakage air flow for subsequent tests, the leakage flow for the subsequent tests was assumed to be zero although in actuality some leakage existed.

Heat Input of Combustion Air

The sensible heat input of the combustion air to the process was calculated as follows. Using the previously determined humidity ratio (ω), and the total air mixture flow, the mass of dry air and the mass of water vapor were determined from the following equations:

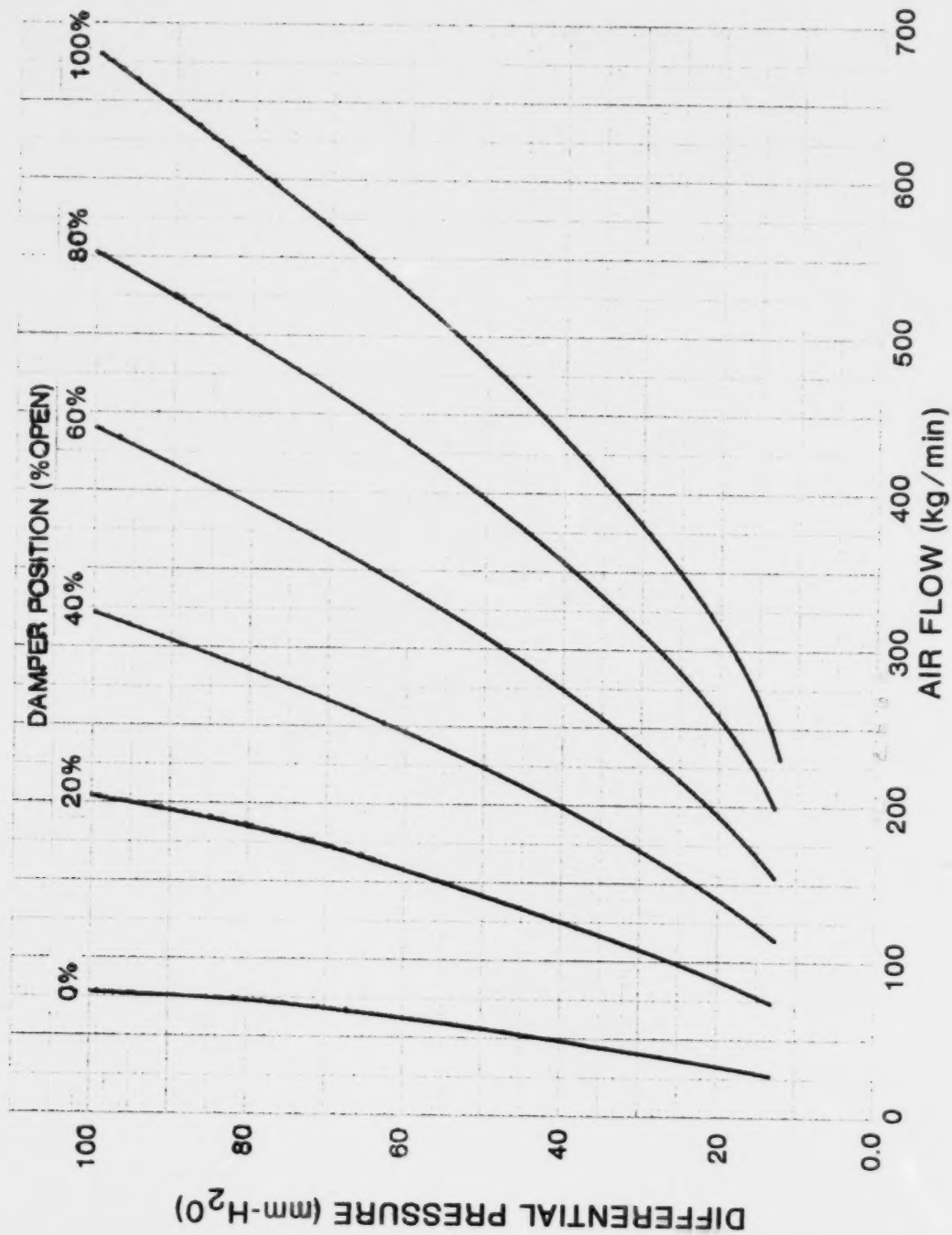


Figure B-17. Flow through butterfly quench damper.

$$M_{Ax} = M_{ax} / (1 + \omega)$$

and

$$M_{\omega x} = M_{ax} - M_{Ax}$$

Sensible heat is then calculated from

$$q_{Ax} = M_{Ax} \cdot h_A$$

$$q_{\omega x} = M_{\omega x} \cdot h_u$$

Where h_A and h_u are the enthalpies of dry air and water vapor at the ambient temperature referenced to 273°K.

For simplicity of presentation, the sum of all $q_{\omega x}$ for the kiln is presented, with the kiln balance and the sum of all $q_{\omega x}$ for the gas purifier is presented with the gas purifier balance.

HEAT LOSS THROUGH VESSEL WALLS

The loss through the vessel walls was originally to be calculated by multiplying the surface area of the vessel by the differential temperature between the vessel surface and the ambient air, and overall heat transfer coefficient. To measure the surface temperature of the various vessels a surface contact and an optical pyrometer were used. Only the thermal vessels and ducts between the kiln and boiler-economizer discharge duct were measured since losses beyond this point were not important. For various reasons the surface heat loss from each of the vessels was determined differently as discussed below.

Kiln Heat Loss

Calculation of the kiln heat loss was performed using both an analytical and an empirical approach to provide a check on the validity of the results. Figures B-18 through B-24 present various temperature profiles along the length of the kiln.

Analytical Method

At any point that a temperature differential and a heat transfer coefficient can be determined the heat transfer rate can be calculated. The total heat transferred from the kiln surface must pass through three interfaces between the internal gas and the outside air. The temperature differential between the ambient air and the kiln surface are known, and therefore, it is the simplest interface to use. The overall heat transfer at this point is a summation of the radiant and convective heat transfer. To further simplify calculations the kiln was divided into a series of heat transfer surfaces. First, the kiln itself is a rotating cylinder whose axis is approximately horizontal. Then both the feed and fire hoods consist of flat vertical and horizontal surfaces. At the time of the skin temperature measurements there was a wind, changing the situation from free convection to

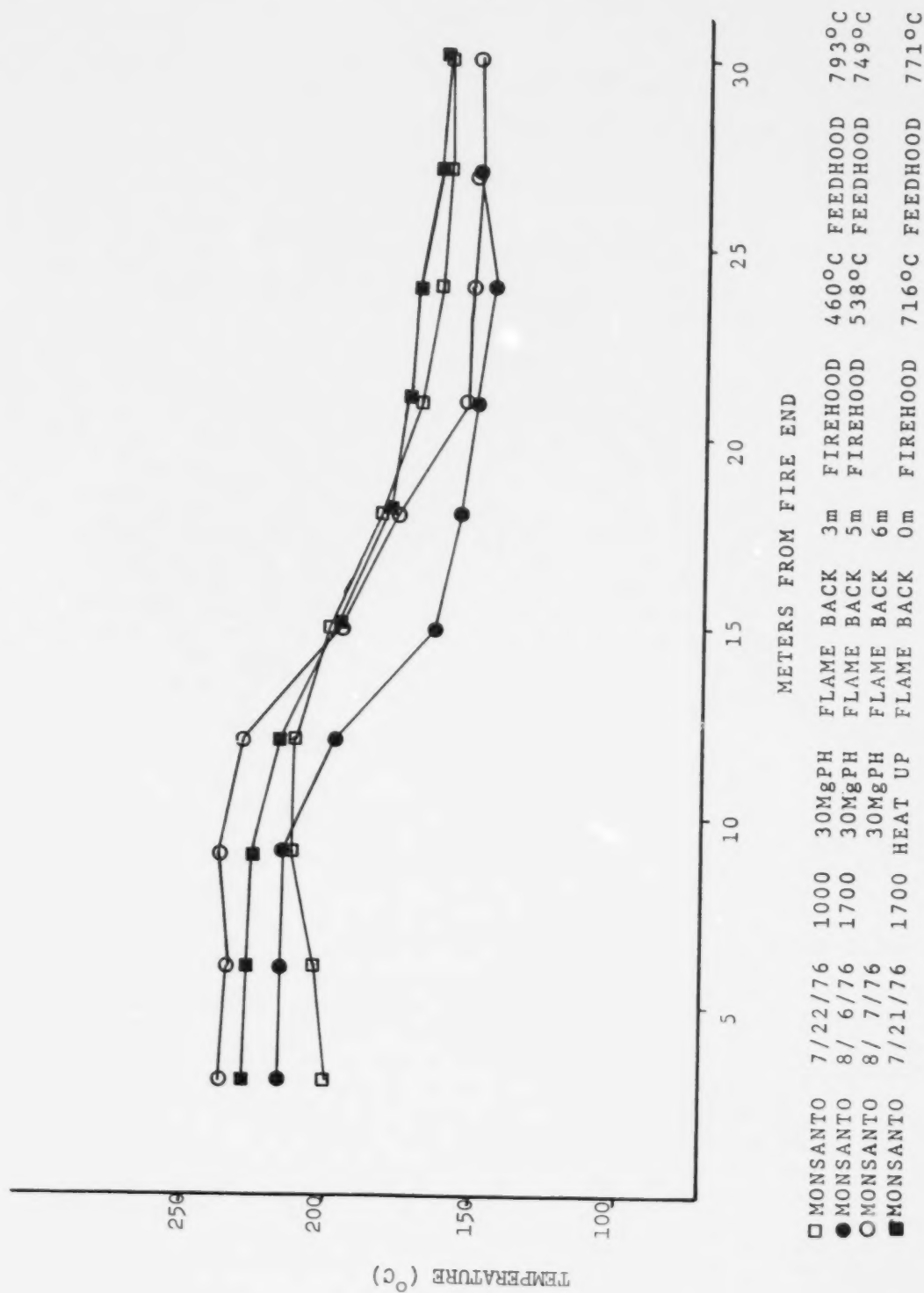


Figure 8-18. Kiln skin temperature profile.

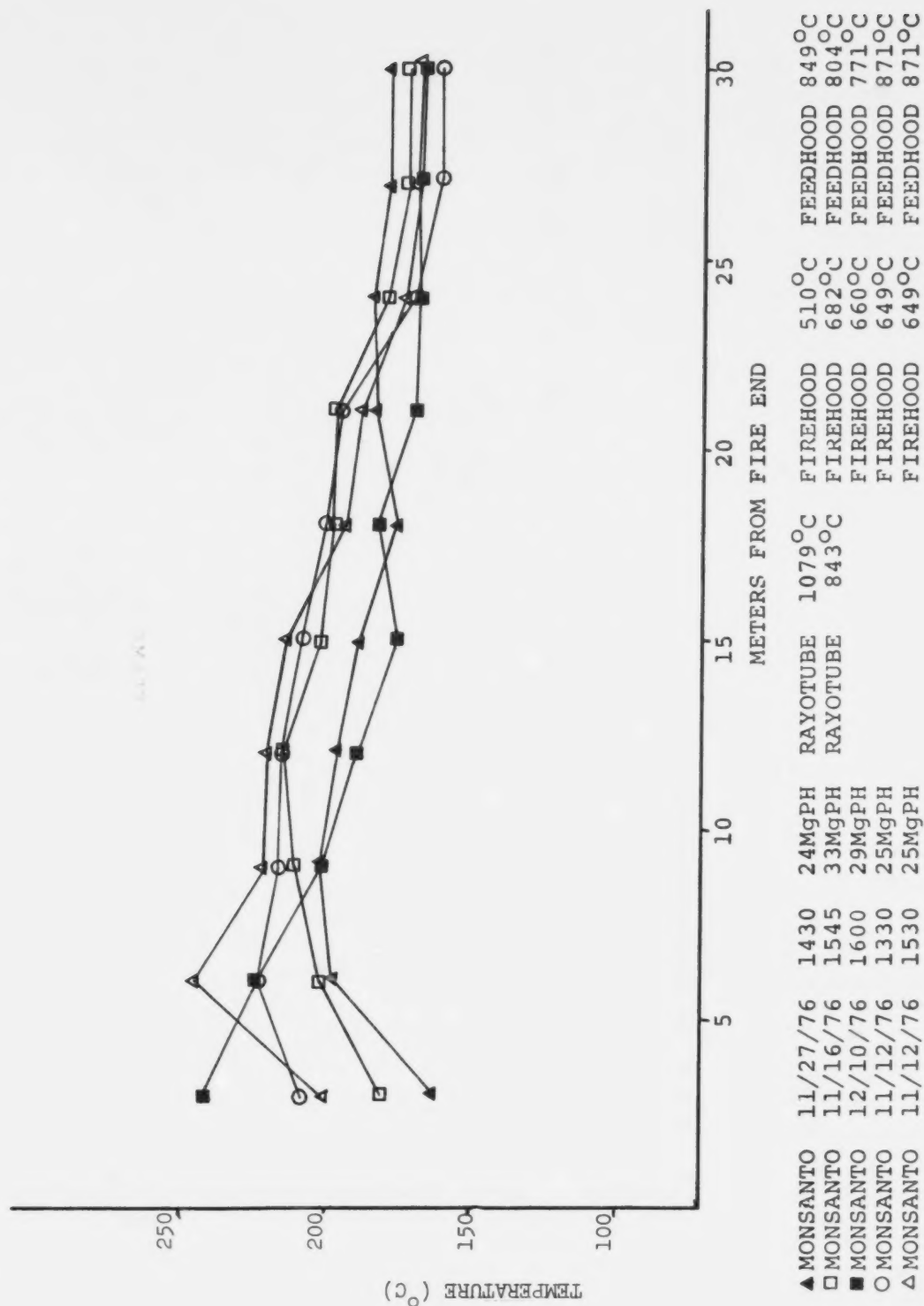
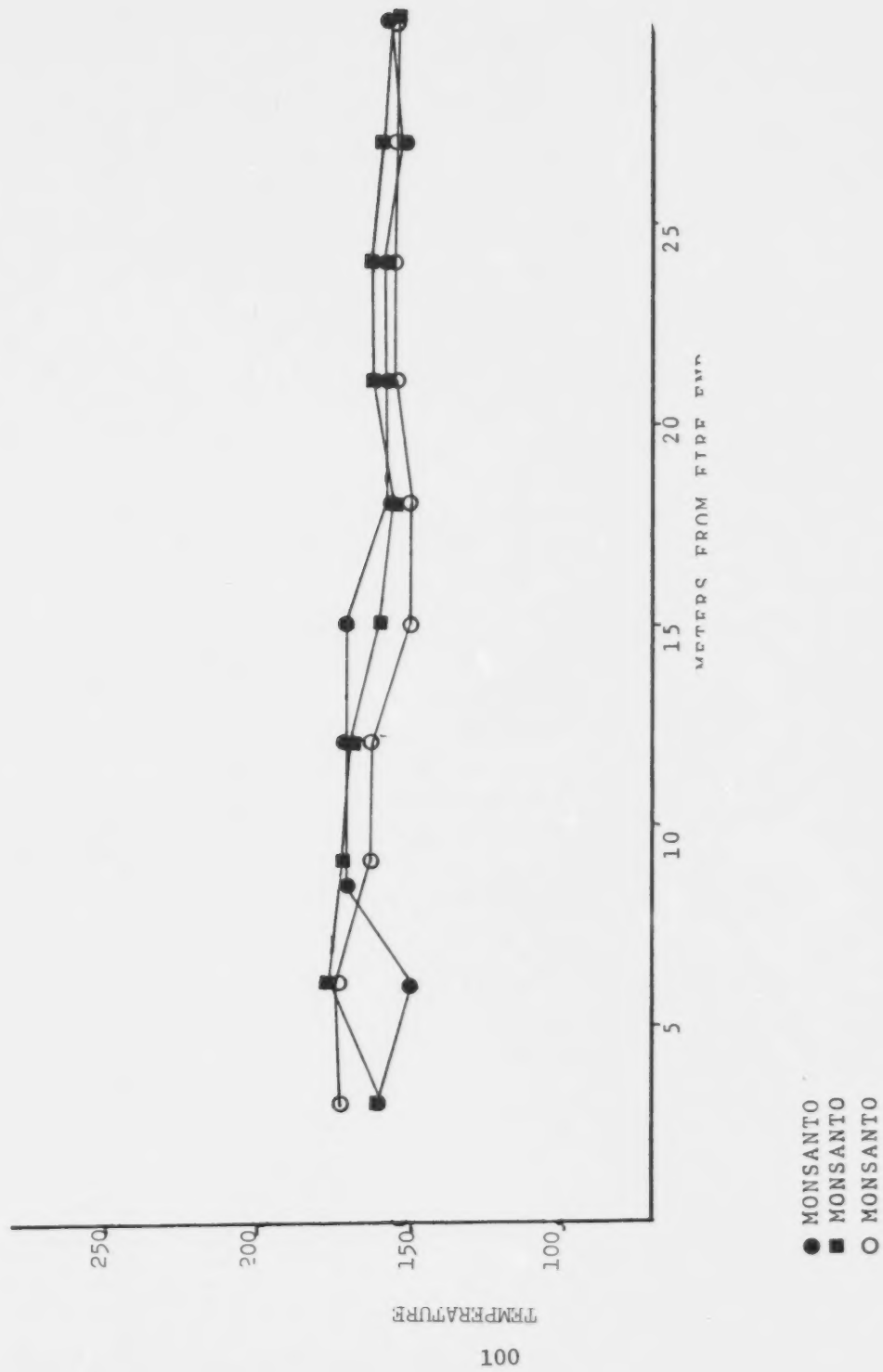


Figure B-19. Kiln skin temperature profile.



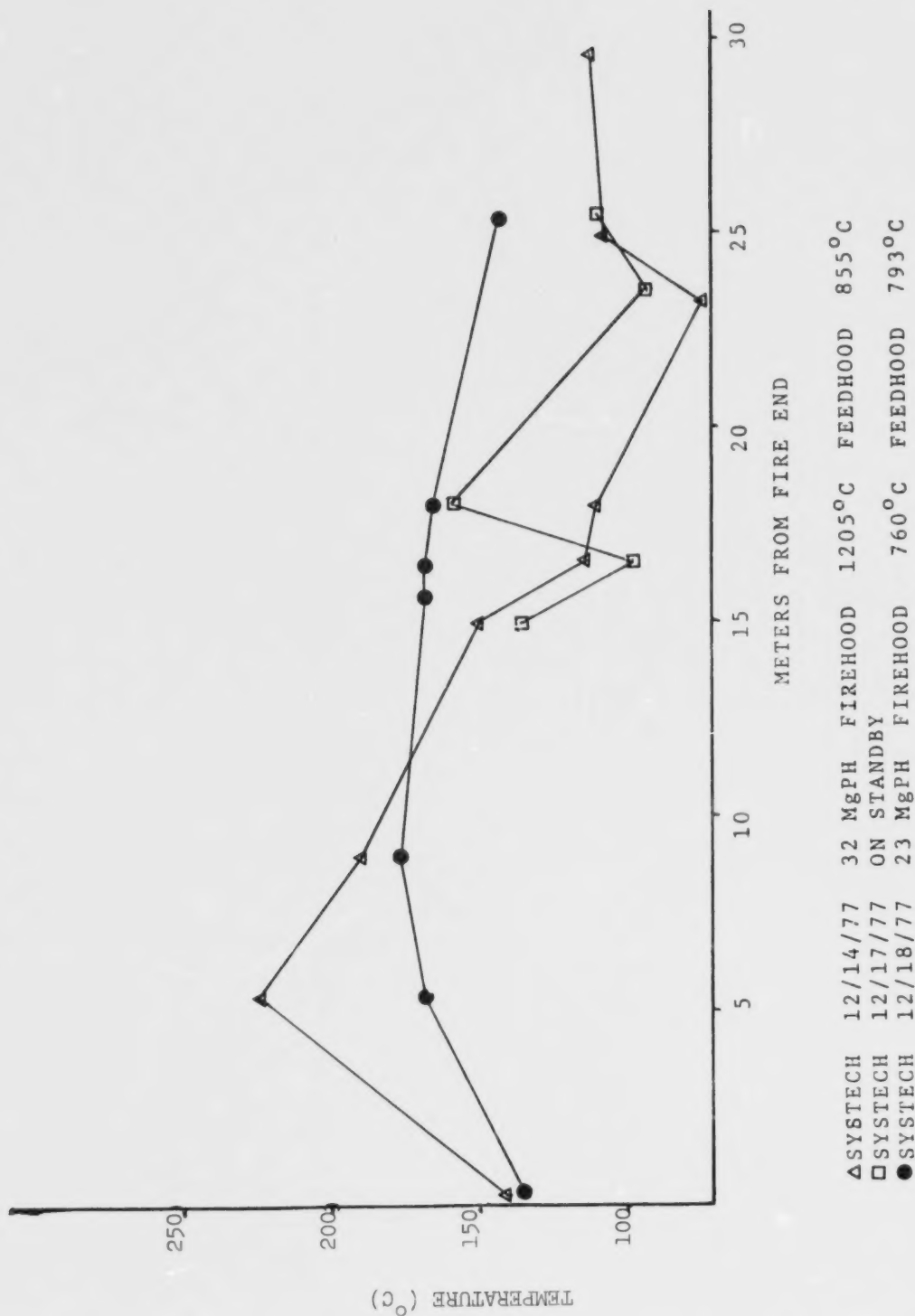


Figure B-21. Kiln skin temperature profile.

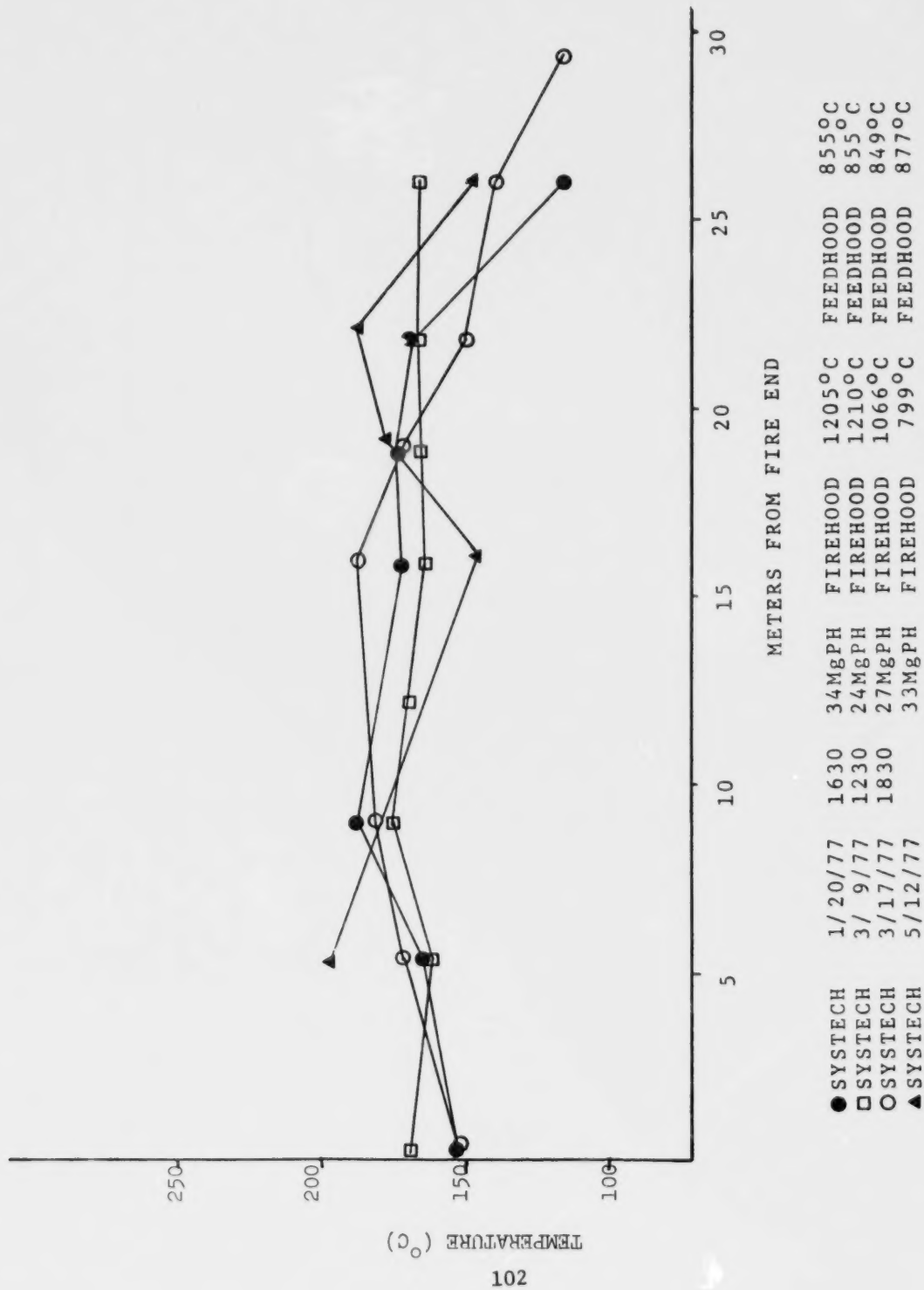


Figure B-22. Kiln skin temperature profile.

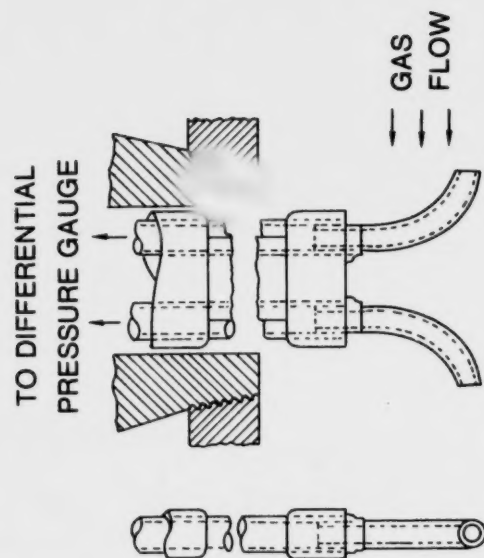


Figure B-23. A combined-reverse static pitot tube.

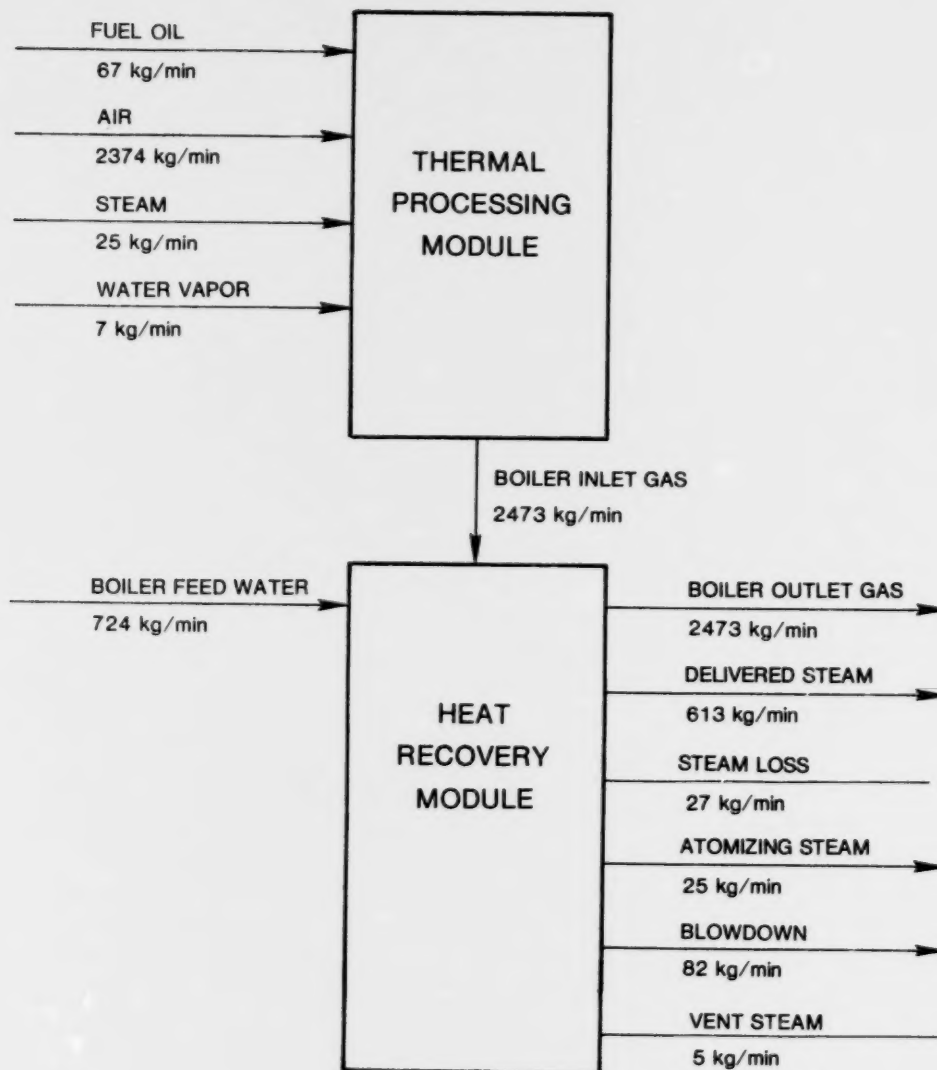


Figure B-24. Standby test mass balance.

forced convection. All the equations used and shown here utilize coefficients and exponents based on English units. Hence, all calculations presented here were made in English engineering units and subsequently converted to metric units.

Radiant Heat Transfer

The first requirement is to determine the surface radiation heat loss component. The equation for this is:

$$q_R = \sigma F_{1-2} A_s (T_s^4 - T_a^4)$$

Assuming the kiln to be a near perfect radiator and the reradiant shape factor to be 1.0 the calculation of q_r becomes:

$$\begin{aligned} q_R &= \sigma A_s (T_s^4 - T_a^4) = \\ &= 1,719 \times 10^{-9} (15483) (800^4 - 530^4) \\ &= 1,467 \times 10^5 \text{ Btu/min. or } 154.8 \text{ MJ/min.} \end{aligned}$$

Convective Heat Transfer

A calculation of the convective components of heat transferred progresses as follows:

$$Re_L = VL/\mu = 3.17 \times 10^6$$

Therefore, the boundary layer is influenced by turbulent flow. Hence the equation for turbulent flow when the surface length is much greater than the critical distance to initiate turbulent flow is:

$$Nu = \frac{h_c L}{k} = 0.036 Pr^{1/3} Re_L^{0.8} = 5227$$

$$\text{then } h_c = .0505 \text{ Btu/ft}^2 \text{ min or } 1.03 \times 10^{-3} \text{ MJ/m}^2 \text{ min } ^\circ K$$

$$\text{therefore } q_c = h_c A \Delta T = .733 \times 10^5 \text{ Btu/min or } 77.3 \text{ MJ/min}$$

for the firehood and feedhood vertical and horizontal surfaces which are parallel to the velocity vector of the wind.

For turbulent free convection from those surfaces perpendicular to the wind velocity vector where the $Gr > 10^{10}$

$$Nu_L = 0.024 \left(\frac{Pr^{1.17}}{1 + .454 Pr^{2/3}} Gr_L \right)^{2/5}$$

$$Gr = 1.469 \times 10^{13}$$

$$\text{Substituting } Nu_L = 3328$$

$$\text{then} \quad h_c = \frac{Nu_L k}{L} = .0241 \frac{\text{Btu}}{\text{ft}^2 \text{ min } ^\circ\text{R}} \text{ or } 4.93 \times 10^{-4} \frac{\text{MJ}}{\text{m}^2 \text{ min } ^\circ\text{K}}$$

$$\text{therefore} \quad q_c = .208 \times 10^5 \text{ Btu/min or } 21.9 \text{ MJ/min}$$

for those vertical surfaces perpendicular to the wind velocity vector. Convective heat transfer from a rotating cylinder is calculated from:

$$Nu = \frac{h_c D}{k} = 0.11 [(0.5 Re_w^2 + Gr) Pr]^{0.35}$$

$$\text{if} \quad Re_w > 8000$$

where Re_w is the Reynolds number for a rotating cylinder calculated from:

$$Re_w = \frac{w \pi D^2}{v}$$

$$\text{substituting} \quad Re_w = 2.00 \times 10^6$$

$$\text{then} \quad Nu = 2491$$

$$\text{and} \quad h_c = 0.036 \text{ Btu/min ft}^2 \text{ } ^\circ\text{R or } 7.36 \times 10^{-4} \frac{\text{MS}}{\text{m}^2 \text{ min } ^\circ\text{K}}$$

$$\text{then} \quad q_c = 0.613 \times 10^5 \text{ Btu/min or } 64.7 \text{ MJ/min}$$

Summing all of the heat transfer components

$$q = 318.7 \text{ MJ/min}$$

Empirical Method

The alternative approach used to determine kiln heat loss was to calculate the total input heat and determine the output heat flow based on measured kiln discharge temperature and calculated mass flow. The difference must be heat lost by the kiln.

The test used for this purpose was the standby test of Jun 28, 1977 at 1530. In this test, the fuel heat input is well known and the fuel at the kiln exit is assumed to be completely combusted based upon the high oxygen levels (14 percent). The important point in this statement is that during pyrolysis of refuse, the refuse is not completely combusted and a similar balance of heat input and discharge of sensible heat from the kiln would not provide information leading to a true kiln skin heat loss evaluation. There are two reasons for this; heat input would not be accurately known, and potential heat discharged as uncombusted gas would not be evaluated. For these reasons only a standby test can be used to determine heat lost through a heat balance.

According to the standby test the energy inputs to the kiln are air (26.3 MJ/min), atomizing steam (17.7 MJ/min), and fuel oil (758 MJ/min) for a total energy input of 802.2 MJ/min. The only energy output besides surface heat loss is the kiln-off gas which has an energy output rate of 426.7 MJ/min. The difference of 375.5 MJ/min is therefore the surface heat loss.

Comparing the heat losses estimated by analytical heat transfer and empirical heat balancing there is reasonably good agreement of the two values with a deviation of 15 percent assuming that the heat balance is considered accurate.

Gas Purifier Heat Loss

The gas purifier has had a tendency as a result of both thinned refractory and high heat loading to have rather high skin temperatures (Table B-40). As a means of lowering skin temperatures, a water manifold was installed which sprayed water onto the top of the gas purifier and that water was allowed to run around the perimeter to a point where that water which was not vaporized ran off of the under side of the cylindrical shell. This means of lowering the skin temperature is effective but develops a random pattern of flow over the shell surface. The gas purifier heat loss cannot be determined analytically because of high, but unknown, tangential internal gas velocities, uneven thickness of refractory insulation, and random patterns of cooling water flow on the shell surface. The only possible means of calculating heat loss is to calculate or measure all heat inputs to the process and calculate or measure all lost or delivered heat outputs. The difference between the two numbers should be representative of the gas purifier heat loss.

The only case in which all inputs are reasonably well known is the standby test of June 28, 1977 at 1530 hours. Based upon this balance which is discussed in detail in a subsequent section, the gas purifier surface heat loss rate is 617.2 MJ/min.

Boiler-Economizer Heat Loss

Since the actual calculation of the boiler surface heat loss rate requires the evaluation of parameters not easily determined, it was decided to assume that the boilers have typical losses. Therefore, while boiler surface temperatures were measured and found to be in the range of 316°K, the boiler surface heat loss was estimated to be 1 percent of the incoming heat flow based upon the curves reported by the American Boiler Manufacturers Association.*

The economizer surface heat loss was conservatively estimated to be 2.5 percent of the incoming heat flow for lack of better information. This is quite possible since the surface temperature of the economizers was much hotter, generally in the range of 466°K.

*The Babcock and Wilcox Company. Steam--Its Generation and Use. 38th Ed. Babcock and Wilcox Company, New York, New York, 1972.

TABLE B-40. GAS PURIFIER SKIN TEMPERATURE

DATE	TIME	AMBIENT TEMP. (°C)	AMBIENT RELATIVE HUMIDITY (%)	WIND VELOCITY (m/min.)	METERS FROM BURNER END (m)	SURFACE TEMP. (°C)
9/25/75*		18	Rain		.3	204
					7.6	218
					15.2	204
9/25/75*		18	Rain		.3	273
					7.6	273
					15.2	273
12/14/76		2	42	375	.3	271
					4.6	296
					10.7	266
					13.7	238
12/18/76		9	40	321	.3	256
					4.6	351
					10.7	353
					13.7	283
1/20/77	1500	1	52	321	.3	239
					2.1	262
					4.6	266
					6.1	366
					7.6	297
					10.7	282
					13.7	267
2/22/77	1600	16	36	321	.3	276
					2.1	287
					10.7	374
3/9/77	1230	16	58	80	.3	288
					2.1	299
					4.6	288
					6.1	399
					7.6	343
					10.7	327
					13.7	327
					15.2	293
3/17/77	1800	14	31		2.1	350
					4.6	388
					7.6	360
					10.7	321
					13.7	310
5/3/77	1600	24	30	321	.3	279
					2.1	299
					3.0	318
					4.5	368
					6.1	427
					7.6	382
					10.7	371
					13.7	321

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 45.

Deaerating Heater Heat Loss

The deaerating heater had an uniform and consistent average surface temperature of 466°K. The skin heat loss is calculated based on a free convection over a horizontal cylinder. The heat loss was calculated using English units and the results were converted to metric. In order to know which equation to use for calculating the convective heat transfer coefficient (h_c) the Grashof number (Gr) must be calculated using the following formula:

$$Gr = \frac{g\beta\rho^2\Delta TL^3}{\mu^2}$$

The diameter of the cylinder (L), and the temperature differential between the deaerating heater surface and the ambient air (ΔT) are known. As taken from a reference table* the unit $g\beta\rho^2/\mu^2$ is equal to 1.35×10^6 for a mean air temperature of 38°C (100°F). The Grashof number can then be calculated to be approximately 1.35×10^{11} . Since the Grashof number is between 10^2 and 10^9 the equation for determining the convective heat transfer coefficient for long cylinders is $h_c = 0.18 \Delta T^{1/3}$. For the deaerating heater the convective heat transfer coefficient is equal to $1.95 \times 10^{-2} \text{ MJ/m}^2\text{°K}$. Since the equation for the heat loss rate is $q = h_c A \Delta T$ the heat loss rate is equal to 1.53 MJ/min. This value remains relatively fixed, varying only in response to changes in ΔT . Since the internal temperature and the surface temperature change very little, the ambient temperature are factored into a ΔT for each test and the resulting q is calculated.

Duct Heat Loss

Because of the methods used to calculate the heat loss from the various vessels all of the duct heat losses have been included with one vessel or another except for the boiler-economizer discharge duct. The following analysis estimates the heat loss rate from this section of ducting based on free convection from a horizontal cylinder, forced convection inside the duct, and radiation from a grey steel surface.

The total heat transfer can therefore be calculated by summing the convective and radiation heat losses as shown by the following equation:

$$q_{dL} = A (U \Delta T + \sigma \epsilon (T_s^4 - T_a^4))$$

The overall heat transfer coefficient (U) can be calculated by the following equation:

$$U = \frac{1}{R_{CI} + R_K + R_{CO}}$$

The various heat resistences can be calculated using the following formulas:

$$R_{CI} = \frac{1}{h_{CI}}$$

$$R_K = \frac{t}{k}$$

$$R_{CO} = \frac{1}{h_{CO}}$$

To determine the heat transfer coefficient for forced convection in a duct (h_{CI}), the Reynolds number (Re) must be determined from the average film temperature which was estimated to be $422^\circ K$. Since the Reynolds number was approximately 8.42×10^5 the flow is turbulent. The equation for heat transfer coefficient in a duct with turbulent flow is:

$$h_{CI} = \frac{0.023}{60} \frac{k}{D} Re^{0.8} Pr^{0.33}$$

From the equation h_{CI} equals $(0.05 \text{ Btu/ft}^2 \text{ min } ^\circ R) 1.02 \times 10^{-3} \text{ MJ/m}^2 \text{ min } ^\circ K$. R_{CI} can then be calculated to equal $978.4 \text{ m}^2 \text{ min } ^\circ K/\text{MJ}$.

The conductive thermal resistance is:

$$R_K = \frac{t}{k} = \frac{.05 \text{ ft}^2 \text{ min } ^\circ R}{\text{Btu}} \text{ or } \frac{2.446 \text{ } ^\circ K \text{ min m}^2}{\text{MJ}}$$

The coefficient for convective heat transfer from the outside duct is determined after first determining the flow characteristics from the Grashof number (Gr) which equals 2.2×10^{10} . Therefore the equation for h_{CO} is:

$$h_{CO} = 0.18 \Delta T^{1/3}$$

Evaluating the equation $h_{CO} = (0.011 \text{ Btu/ft}^2 \text{ min } ^\circ R) 2.26 \times 10^{-4} \text{ MJ/m}^2 \text{ min } ^\circ K$. R_{CO} can then be calculated and $R_{CO} = 4.425 \times 10^3 \text{ m}^2 \text{ min } ^\circ K/\text{MJ}$. The overall heat transfer coefficient (U) can then be calculated and found to equal $1.85 \times 10^{-4} \text{ MJ/m}^2 \text{ min } ^\circ K$. The convective heat transfer can then be calculated using the following equation, $q_c = UA \Delta T$ to equal 4.96 MJ/min .

Since all the heat leaving the duct must pass all interface surfaces, the surface temperature can be determined from:

$$T_I - T_S = (T_I - T_A) \left(\frac{R_{CI} + R_K}{R_{CI} + R_K + R_{CO}} \right)$$

Evaluating the equation $T_I - T_S = 23.4^\circ K$ or T_S equals $391^\circ K$. Then calculating the radiation component of the duct heat loss from

$$q_R = \sigma \epsilon A (T_S^4 - T_a^4)$$

where ϵ for the surface is approximately 0.42 the radiant heat transfer rate q_R equals $(4.187 \times 10^3 \text{ Btu/min}) 4.417/\text{MJ min}$.

Summing the total heat loss by the duct $q_{dL} = q_c + q_R = 9.38 \text{ MJ/min}$. A simplified means of determining the heat transfer for other tests is to utilize the value obtained and evaluate an overall heat transfer coefficient as $q_{dL} = C \Delta T$ which assumes that the heat transfer coefficients do not change appreciably and the absolute temperature levels remain relatively constant. If this is true, then $q_{dL} = 7.278 \times 10^{-2} \Delta T$ is the equation for use in calculating the boiler-economizer discharge duct heat loss for the remaining tests.

DUCT GAS FLOW MEASUREMENTS

Gas flows at the kiln crossover duct, the gas purifier exit duct, and the boiler-economizer outlet duct were calculated by using a combined-reverse static (S-type) pitot tube velocity measurements, orsat gas analyses, and gas temperature measurements. All measurements were made in English units and the results were subsequently converted to metric units.

The pitot tubes used (Figure B-23) were approximately 1.5 m (5 ft.) long, and were made of stainless steel tubing. The pitot tubes were tested to determine the calibration pressure constant C_p . Because of the turbulent flow in the ducts the velocity was fairly uniform across the cross section of the duct. Therefore, only the estimated average pitot tube measurement was used. To determine the pressure differential in inches of water, the measured differential pressure was multiplied by the calibration pressure constant, and the specific gravity of the oil in the manometer.

When possible, the duct static pressure was measured, otherwise, an estimated value of 101 kPa (2110 lbs./ft.²) was used.

The moisture content of the gas was measured using water traps and a dry gas meter. When the moisture content was not available, it was estimated by calculating the moisture entering the process from those locations where moisture content was available. The relative impact caused by a moisture content estimate error on the total gas flow calculation was investigated using a method of partial differentiation. It was determined that a 5 percent error in the moisture content would cause a 0.7 percent error in the total mass flow. Similarly, a 10 percent error in the moisture content results in a 1.4 percent total mass flow error. The consequence of these statements is that relatively large errors in the measurement and estimation of the water content of the gas results in insignificant mass flow errors.

The composition of the gases at the various measurement points was determined by a variety of techniques. Monsanto used orsat, firite and mass spectrographic analyses, while Systech used orsat and gas chromatograph analyses to determine the volume percentage of each gas.

During all operations, temperature measurements were made by either a calibrated thermocouple probe, fixed facility thermocouple probes, or both, depending upon the temperature level being measured. If gas temperatures

were below 1090°K (1060°R), then measurements were made with both the calibrated thermocouple and facility probes at those locations where facility probes existed. When temperatures were above 1090°K, measurements were obtained only through permanent facility thermocouple probes.

During the standby test, it was noted that measurements at the crossover duct made by the calibrated thermocouple and facility probe differed by 64K° or nearly 8 percent. This is sufficiently high to indicate error in the facility measurement system.

Thermocouple temperature measurements at relatively steady state conditions can include only a few simple errors. This does not infer that correction of those errors is a simple task. For example, the thermocouple junction itself suffers very little degradation with usage and as long as the junction is intact, it functions satisfactorily. Errors generally are found in the reference junction temperature, secondary junction temperatures (caused by insertion of readout instruments in the circuit), and readout instrument errors. In the Baltimore pyrolysis plant, temperatures are not referenced to the ice point (273°K) or the standard reference (339°), but rather are left to float with the ambient temperature. This is normal heavy industry practice since the result, especially for very high temperatures (>1100°K) usually represents an error of less than 5 percent which is quite acceptable in most instances. The thermocouple lead wire composition is not known, i.e., copper conductor or alloy conductor, therefore the error potential of secondary junctions cannot be evaluated. The readout instrument is located in the control room which is temperature controlled to 294° - 300°K but it is anticipated that the interior of the instrumentation cabinets reaches 310° - 325°K due to heat generated by the process control electronics. No specific evaluation of the readout instrument error has been made, but comparisons can be made.

To estimate this error, the kiln-off gas temperature, as measured by the calibrated thermocouple and the permanent facility thermocouple were compared. The facility thermocouple was consistently 78K° higher than the calibrated thermocouple. It was therefore assumed that the facility thermocouple had a systematic error of 78K° which should be subtracted to obtain the correct temperature.

Using the molar weight of each gas, the mass percentage of each gas was calculated from the volume percentage along with the molar weight of the mixture. The density of the gas mixture was then determined using the ideal gas law. The velocity of the gas flow in each duct was then calculated using the following formula:

$$V = C_p \frac{2g \gamma_w \Delta p}{12 \rho}$$

Having determined the velocity, the volumetric gas flow rate in each duct was determined by multiplying the velocity by the crosssectional area of each duct. The mass flow rate for each duct was calculated by multiplying the volumetric flow rate by the density of the gas mixture. Descriptions

of the various duct sampling crosssections along with the flow coefficient and temperature measurements of each crosssection are reported in following separate subsections.

Calculation of the heat flow at the various duct measurement points progressed similar to the method used to calculate the sensible heat of the air entering the process through the fans. The measured total temperature enthalpy of each gas constituent was determined and referenced to 273°K. The heat flow rate for each constituent was calculated by multiplying the mass flow rate by the enthalpy for each constituent. The total heat flow rate was then equal to the sum of the heat flow rates for the constituents.

Kiln Feedhood and Crossover Duct

Measurements were taken at the kiln feedhood and the kiln crossover duct to characterize the kiln-off gases which is an output from the kiln and an input to the gas purifier. All of the feedhood data was collected by Monsanto. Because of the irregular flow patterns within the feedhood, very little can be ascertained from the data. However, for completeness, the data is presented.

The feedhood orsats are shown in Table B-40a. These values are from early in the demonstration and do not reflect the present kiln operation.

The feedhood particulate loadings, shown in Table B-41, reveal that the kiln-off gas composition varies considerably. The particle size distribution of the feedhood particulate is shown in Table B-42.

Various methods were used to analyze the composition of the feedhood particulate. The ultimate analysis of the particulate is shown in Table B-43, while the particulate ultimate analysis by size distribution is shown in Table B-44. Spectrographic analysis of the feedhood particulate are shown in Table B-45, and the spectrographic analysis by size distribution is shown in Table B-46. X-ray diffraction analyses of feedhood particulate are shown in Tables B-47 and B-48 with Table B-48 revealing the analysis according to size distribution. Tables B-49 and B-50 present the X-ray fluorescence analyses of feedhood particulate by size distribution.

As discussed in Volume II of this report, there were many methods used to characterize the composition. Since only the mean value from each method was shown in that volume, the remaining data will be presented. The mass spectrographic analysis data is presented in Table B-51 and the hydrocarbon analysis data is shown in Table B-52. All of this data was collected by Monsanto EnviroChem while the remaining kiln-off gas data was collected by Systech.

Table B-53 is the crossover orsat data. This data was obtained using both a stainless steel tube and a stainless steel water-cooled tube as the collection probe. The use of a water-cooled probe had little effect on the results. The flame ionization detection (FID) gas chromatograph data is

TABLE B-40a. FEEDHOOD ORSTATS

Date	Time	CO ₂ %	O ₂ %	CO%	Date	Time	CO ₂ %	O ₂ %	CO%
4/09/75*	2345	11.20	3.30	8.50	5/20/75†	1757	13.05	2.35	7.15
4/10/75*	1215	10.50	6.50	5.00	5/30/75†	1446	13.40	2.50	5.60
4/22/75*	1215	4.00	14.70	2.50	5/31/75†	1208	13.40	2.60	4.85
4/27/75*	1338	9.40	7.00	5.00	6/01/75†	1920	13.55	2.55	5.00
4/28/75*	0350	13.00	1.30	10.00	6/02/75†	1515	12.10	2.65	8.50
4/28/75*	1720	2.90	16.20	1.70	6/13/75†	1146	15.00	1.80	1.40
5/11/75†	2350	13.30	3.40	7.30	6/13/75†	1623	10.20	7.80	3.10
5/12/75†	1135	11.05	4.80	4.90	6/20/75*	0425	11.00	6.00	2.90
5/12/75†	1908	10.65	5.70	4.55	6/21/75*	0802	12.95	2.50	7.50
5/19/75†	1310	15.50	1.20	5.20	6/28/75*	1435	12.70	2.20	5.10
5/19/75†	1400	15.50	1.20	5.20	7/02/75*	1018	13.10	3.00	4.20
5/19/75†	2334	13.00	2.20	6.60	7/02/75*	1907	13.25	4.35	6.00
Average									
							11.66	4.49	5.32
Standard Deviation									
							2.93	3.78	2.10

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 3.

† Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 2.

TABLE B-41. FEEDHOOD PARTICULATE LOADINGS

Date	Time	Method	Loadings g/DSCM (21°C)
4/09/75	2345	Modified Buell*	48.22
4/10/75	1215	Modified Buell*	25.78
4/10/75	1305	Modified Buell*	32.01
4/22/75	1215	Modified Buell*	43.55
4/27/75	0628	Modified Buell*	42.29
4/27/75	1338	Modified Buell*	43.57
4/28/75	0350	Modified Buell*	36.06
4/28/75	1720	Modified Buell*	41.60
4/28/75	2110	Modified Buell*	67.41
5/11/75	2350	ASME†	15.57
5/12/75	1135	ASME†	28.60
5/12/75	1908	ASME†	23.90
5/19/75	1310	ASME†	15.07
5/19/75	1400	Modified Buell*	55.90
5/19/75	2334	ASME†	20.52
5/20/75	1757	ASME†	13.72
5/30/75	1446	ASME†	114.62
5/31/75	1208	ASME†	124.13
6/01/75	1920	ASME†	155.31
6/02/75	1515	ASME†	56.76
6/13/75	1146	ASME†	29.99
6/13/75	1623	ASME†	42.93
6/16/75	0830	Modified Buell*	26.81
6/20/75	0425	Modified Buell*	34.05
6/21/75	0802	Modified Buell*	37.64
6/28/75	1435	Modified Buell*	37.91
7/02/75	1018	Modified Buell*	31.14
7/02/75	1907	Modified Buell*	94.11

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 3.

† Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 2.

TABLE B-42. PARTICLE SIZE ANALYSIS OF FEED HOOD PARTICULATE

Collected 5/27/75*		
Particle Size (microns)	Weight (grams)	%
0 - 1.45	0.343	5.36
1.45 - 2.36	0.497	7.77
2.36 - 5.09	0.803	12.56
5.09 - 8.25	0.909	14.21
8.25 - 13.64	0.941	14.70
13.64 - 26.21	0.806	12.61
26.21 - 40.03	0.355	5.55
40.03 - 80 Mesh	1.215	19.08
+80 Mesh	0.500	7.85

Collected 6/28/75 (1435)+		
Particle Size (microns)	Weight (grams)	%
0 - 1.53	0.467	8.0
1.53 - 2.49	0.630	10.8
2.49 - 5.39	1.073	18.4
5.39 - 8.72	0.923	15.8
8.72 - 14.43	0.747	12.8
14.43 - 27.72	0.521	8.9
27.72 - 42.34	0.232	4.0
42.34 - 80.00	1.242	21.3
+80	0.000	0.0

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 6.

† Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. Table 9.

TABLE B-43. ULTIMATE ANALYSIS OF 4 BUELL FILTERS AND
SAMPLE COLLECTED FROM FEED HOOD*

Date Time	4/9/75 2345 %	4/10/75 1215 %	4/10/75 1305 %	4/22/75 1215 %
Nitrogen	0.17	0.12	0.20	0.18
Carbon	56.83	35.37	58.03	44.51
Hydrogen	0.48	0.38	0.48	0.88
Ash	-	-	-	46.92
Sodium as is	-	-	-	1.30
Sodium in ash	-	-	-	2.24
Chloride as is	-	-	-	0.74
Chloride in ash	-	-	-	<0.08

* Herrington, R. D., D. E. Honaker, and B. G. Ward. Baltimore Landgard®
Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240.
St. Louis, Missouri, 1976. Table 4.

TABLE B-44. ULTIMATE ANALYSIS OF FEED HOOD PARTICULATES*†

Sample (microns)	%C	%H	%N
0 - 1.53	87.84	-	-
1.53 - 2.49	81.72	0.63	0.30
2.49 - 5.39	67.73	0.51	0.27
5.39 - 8.72	53.93	0.35	0.51
8.72 - 14.43	38.67	-	-
14.43 - 27.72	00.49	0.14	0.37
27.72 - 42.34	9.94	0.04	0.24
42.34 - 80.00	7.13	-	-

* Sample collected 6/28/75 at 1435.

† Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard®
Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240.
St. Louis, Missouri, 1976. Table 10.

TABLE B-45. SPECTROGRAPHIC ANALYSIS OF 4 BUELL FILTERS
AND SAMPLE COLLECTED FROM FEED HOOD*

ELEMENT	4/9/75 (%)	4/10/75 (%)	4/10/75 (%)	4/22/75 (%)
Titanium	0.100-1.000	0.100-1.000	0.100-1.000	0.100-1.000
Nickel	0.100-1.000	0.100-1.000	0.100-1.000	0.010-0.100
Potassium	0.500-5.000	0.500-5.000	0.500-5.000	0.500-5.000
Cobalt	0.001-0.010	0.001-0.010	0.001-0.010	0.001-0.010
Zinc	0.100-1.000	0.500-5.000	0.500-5.000	0.500-5.000
Copper	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100
Sodium	1-10	1-10	1-10	1-10
Molybdenum	0.001-0.010	0.001-0.010	0.001-0.010	0.005-0.050
Tin	0.010-0.100	0.010-0.100	0.010-0.100	0.050-0.500
Vanadium	0.001-0.010	0.001-0.010	0.001-0.010	0.001-0.010
Calcium	3-30	3-30	3-30	1-10
Iron	1-10	1-10	1-10	1-10
Aluminum	3-30	3-30	3-30	1-10
Bismuth	<0.001	<0.001	<0.001	<0.001
Silicon	3-30	3-30	5-50	3-30
Magnesium	0.500-5.000	0.500-5.000	0.500-5.000	0.100-1.000
Manganese	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100
Chromium	0.050-0.500	0.050-0.500	0.050-0.500	0.100-1.000
Lead	0.010-0.100	0.010-0.100	0.001-0.010	0.030-0.300
Boron	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100
Phosphorus	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100
Beryllium	<0.001	<0.001	<0.001	<0.001
Cadmium	<0.001	<0.001	<0.001	<0.001
Thallium	<0.001	<0.001	<0.001	<0.001
Germanium	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.005	<0.005	<0.005	<0.005
Antimony	<0.005	<0.005	<0.005	<0.005
Silver	0.001-0.010	0.001-0.010	0.001-0.010	0.001-0.010
Strontium	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100
Barium	0.010-0.100	0.010-0.100	0.010-0.100	0.010-0.100

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240 St. Louis, Missouri, 1976. Table 4.

TABLE B-46. SPECTROGRAPHIC EMISSION OF FEED HOOD PARTICULATE*†

Element	Particle Size							
	<1.45 μ	1.45-2.36 μ	2.36-5.09 μ	5.09-8.25 μ	8.25-13.64 μ	13.64-26.21 μ	26.21-40.03 μ	40.30 μ +80 Mesh
Si	>0.100	>0.100	>0.100	>0.100	>0.100	>0.100	>0.100	Major
Al	>0.100	>0.100	Major	Major	Major	Major	Major	Major
Mg	0.080	0.080	>0.100	>0.100	0.100	0.100	>0.100	>0.100
Mn	0.040	0.050	0.070	0.080	0.080	0.100	0.100	0.100
Ca	Major	Major	Major	Major	Major	Major	Major	Major
B	0.005	0.006	0.010	0.010	0.020	0.020	0.020	0.020
Fe	Major	Major	Major	Major	Major	Major	Major	Major
Cr	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008
Cu	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Ni	>0.010	0.020	0.020	0.010	0.010	0.008	0.008	0.008
Mo	0.001	0.001	0.005	0.008	0.008	0.008	0.008	0.007
Sn	0.007	0.007	0.010	0.010	0.010	0.020	0.010	0.010
Na	>0.100	>0.100	>0.100	Major	Major	Major	Major	Major
Ti	0.100	0.100	Major	Major	Major	Major	Major	Major
Zn	Major	Major	Major	Major	Major	Major	Major	Major
Pb	0.060	0.050	0.050	0.030	0.030	0.040	0.030	0.030
Sb	0.010	0.010	0.020	0.008	0.008	0.007	0.007	0.008
V	0.004	0.005	0.008	0.010	0.008	0.008	0.008	0.008
Zr	0.002	0.004	0.005	0.007	0.007	0.007	0.007	0.008
K	§	§	§	§	§	§	§	§
Ba	¶	¶	¶	¶	¶	¶	¶	¶

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 8.

† Sample collected 5/27/75. Detection limits: 0.0001% - 0.1000%. Major indicates a concentration of 1% or greater. Interference indicates that the spectral background is too high for determination of Ba at its wavelength. This is a semi-quantitative technique; therefore, the above results may vary by +20% - 50%.

§ Present.

¶ Interference.

TABLE B-47. X-RAY DIFFRACTION ANALYSIS OF FEED HOOD COMPOSITE PARTICULATE*†

Compound	Peak Height
SiO ₂ (α-quartz)	65
Amorphous	25
NaCl	15

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 11.

† Sample collected 4/28/75, 1435.

TABLE B-48. X-RAY DIFFRACTION ANALYSIS OF FEED HOOD PARTICULATE**

Sample	Amorphous	Al ₂ O ₃	SiO ₂	NaAlSiO ₄	Unknown	Unknown	Fe ₃ O ₄	Fe ₂ O ₃
0- 1.45	175							
1.45- 2.36	100						30	
2.36- 5.09	55						30	
5.09- 8.25	35						30	
8.25-13.64	25+		80	30			20	
13.64-26.21	25		100+(30)§	30	5			
26.21-40.03	25-		100+(70)§	35	10			20
40.03-80 Mesh	10		100+(55)§	40	20			30
+80 Mesh	30	100+	100	10				
			45					

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 7.

† Sample collected 5/27/75.

§ Numbers in parenthesis are second phase peak heights. Numbers give a measure of amount of material present of a relative scale. They are useful in comparison between amounts of like materials in different samples only.

TABLE B-49. X-RAY FLUORESCENCE ANALYSIS OF FEED HOOD PARTICULATE SAMPLE COLLECTED 5/27/75*

SAMPLE (MICRONS)	MAJOR (>1%)	MINOR (0.1-1%)	TRACE (0-0.1%)
0- 1.45	Zn, Fe, Ca, Ti, K	Pb, Mn, Sb, Ni, Cu, Sr, S, Cl	Cr, Sn, Al, Si
1.45- 2.36	Zn, Fe, Ca, Ti, K	Pb, Mn, Sb, Ni, Cu, Sr, Cl, S, Si	Cr, Al
2.36- 5.09	Zn, Fe, Ca, Ti, K, Cl	Pb, Mn, Sb, Ni, Cu, Sr, Si, Al	Sn, Cr, Zr, S
5.09- 8.25	Zn, Fe, K, Cl	Pb, Mn, Sb, Ni, Cu, Ca, Ti, Si, Al	Ba, Zr, Cr, Sr, S
8.25-13.64	Zn, Fe, Cu, Ti, Cl, K, Si	Pb, Sb, Ni, Cu, Sr, Al	Ba, Sn, Zr, Cr
13.64-26.21	Zn, Fe, Ca, Ti, K, Si	Pb, Ba, Cu, Sr, Mn, Cl, Al	Sn, Cr, Zr
26.21-40.03	Zn, Fe, Ca, Ti, Si	Pb, Ba, Cu, Ni, Sr	Sn, Cr, Zr
40.03-80 Mesh	Zn, Fe, Ca, Ti, K, Si	Pb, Ba, Cu, Ni, Sr, Mn, Cl, Al	Sn, Cr, Zr
+80 Mesh	Fe, Al	Zn, Ca, Ti, K, Si	Cr, Zr, Cu, Sr, Mn, S

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 7.

TABLE B-50. X-RAY FLUORESCENCE ANALYSIS OF FEED HOOD PARTICULATE COLLECTED 6/28/75, 1435 HRS.*

SAMPLE (MICRONS)	MAJOR (>1.0%)	MINOR (0.1-1.0%)	TRACE (<0.1%)
0- 1.53	Zn, Fe, Ca, Ti, K	Mn, Cu, S	Pb, Sr, Ni, Cr, Cl, Al, Si
1.53- 2.49	Zn, Fe, Ca, Ti, K	Mn, Cu	Pb, Sr, Sn, Ni, Cr, Cl, S, Si, Al
2.49- 5.39	Zn, Fe, Ca, Ti, K	Mn, Al, Cu, Si	Pb, Sr, Zr, Ba, Ni, Cr, Cl, Sn, S
5.39- 8.72	Zn, Fe, Ca, Ti, K	Mn, Al, Si	Pb, Sr, Zr, Ba, Ni, Cu, Cr, Cl, S
8.72-14.43	Zn, Fe, Ca, Ti, K	Mn, Si, Al	Pb, Sr, Ba, Ni, Cu, Cr, Cl, S
14.43-27.72	Zn, Fe, Ca, Ti, Si, K	Mn, Al	Pb, Sr, Ba, Zr, Sn, Cu, Ni, Cr, S, Cl
27.72-42.34	Zn, Fe, Ca, Ti, K, Si	Mn, Al	Pb, Sr, Ba, Sn, Ni, Cu, Zr, Cr, Cl
42.34-<80	Zn, Fe, Ca, Ti, K, Si	Mn, Al	Pb, Sr, Ba, Ni, Cu, Sn, Zr, Cr, Cl

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 11.

TABLE B-51. MASS SPECTROMETRIC ANALYSIS OF KILN OFF-GAS* (VOLUME %)

DATE TIME	4/ 9/75 -	4/10/75 -	4/22/75 1225	4/27/75 0635	4/27/75 1345	4/28/75 0400	5/30/75 1500	5/30/75 1900
Methane	0.170	0.60	2.20	1.40	1.90	1.80	2.33	0.01
Oxygen	1.70	2.20	2.00	3.20	.60	8.40	-	16.43
Carbon Dioxide	15.10	12.60	13.10	12.80	14.90	8.90	15.66	4.19
Hydrogen	6.10	6.20	11.50	7.90	9.50	5.90	12.96	-
Ethylene	0.50	0.50	0.50	0.30	0.50	0.50	0.36	-
Acetylene	0.10	0.10	-	-	-	-	-	-
Ethane	0.05	0.04	0.10	0.10	TRACE	0.10	0.12	-
Benzene	0.04	0.05	-	-	-	-	-	-
Carbon Monoxide	INTERFERENCE		13.00	7.50	14.50	6.60	12.94	1.15
Argon	-	-	0.60	0.70	0.70	0.70	0.63	0.76
Nitrogen	BAL.	BAL.	57.00	66.10	57.40	67.10	54.99	77.46

DATE TIME	5/31/75 1215	6/ 1/75 1930	6/ 2/75 1530	6/13/75 1150	6/13/75 1630	6/16/75 0837	6/20/75 -	6/21/75 -
Methane	1.72	1.64	1.91	0.53	0.87	0.91	1.11	1.38
Oxygen	-	0.93	0.22	0.14	3.49	2.73	1.48	2.07
Carbon Dioxide	15.15	15.44	13.25	17.09	12.20	13.33	14.49	13.16
Hydrogen	10.80	9.32	12.98	3.66	9.05	10.72	10.35	11.27
Ethylene	0.23	0.29	0.35	-	0.13	0.14	0.19	0.31
Acetylene	-	-	-	-	-	-	-	-
Ethane	0.11	-	0.14	-	0.08	-	0.10	0.11
Benzene	-	-	-	-	-	-	-	-
Carbon Monoxide	12.29	10.03	15.26	6.50	9.79	10.57	8.40	9.86
Argon	0.66	0.69	0.64	0.77	0.68	0.66	0.67	0.65
Nitrogen	59.04	61.66	55.26	71.30	63.71	60.95	63.22	61.18

TABLE B-51. (Continued)

DATE TIME	6/28/75 1445	7/02/75 1915	7/02/75 1930	7/02/75 0830	7/02/75 0830	MINIMUM	MAXIMUM	MEAN
Methane	1.32	2.45	2.19	1.86	1.83	0.01	2.45	1.46
Oxygen	2.11	0.02	0.50	0.13	0.11	-	16.43	2.21
Carbon Dioxide	12.43	14.89	16.75	14.64	15.11	4.19	17.09	13.57
Hydrogen	11.71	11.39	11.27	9.94	9.87	-	12.98	9.16
Ethylene	0.19	0.53	0.49	0.33	0.37	-	0.53	0.32
Acetylene	-	-	-	-	-	0.10	0.10	0.10
Ethane	0.10	0.13	0.13	0.13	0.14	TRACE	0.14	0.09
Benzene	-	-	-	-	-	0.04	0.05	0.04
Carbon Monoxide	10.66	11.13	9.78	10.52	10.06	1.15	12.29	10.03
Argon	0.65	0.65	0.63	0.67	0.67	0.60	0.77	0.67
Nitrogen	60.83	58.82	58.26	61.78	61.84	54.99	77.46	61.99

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 12.

TABLE B-52. TOTAL HYDROCARBON ANALYSIS OF KILN OFF-GAS*

DATE	TIME	TOTAL HYDROCARBON AS CH ₄ (ppm)	CH ₄ CONTENT (ppm)	CO CONTENT (%)
3/14/75	2320	>6,500	4,780	-
4/10/75	-	15,000	+	>2
4/19/75	-	15,000	+	>2

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 5.

† Not measured due to CO interference.

TABLE B-53. CROSSOVER DUCT ORSATS

Date	Time	CO ₂ %	O ₂ %	CO%	Date	Time	CO ₂ %	O ₂ %	CO%
11/15/76	1215	15.5	.6	5.0	1/13/77	1700	15.2	1.4	5.8
11/15/76	1530	12.0	.2	6.8	1/15/77	1530	14.8	1.0	7.0
11/16/76	1400	12.4	1.6	7.0	1/19/77	1455	16.2	1.2	5.2
12/07/76	1530	14.6	1.6	5.6	1/20/77	1250	14.6	1.6	5.8
12/07/76	1745	14.6	.4	5.8	1/23/77	1145	14.8	1.2	7.0
12/09/76	1845	15.6	.8	4.6	1/31/77	0800	14.6	.4	5.6
12/10/76	1330	14.6	.0	5.4	2/01/77	1430	13.8	1.0	4.6
12/10/76	1900	14.4	.0	6.0	2/22/77	1430	13.8	.2	7.4
12/12/76	1340	13.8	.6	5.8	2/24/77	1330	13.4	1.0	6.6
12/13/76	1310	14.4	1.0	8.8	5/10/77		14.8	.6	3.0
12/13/76	1710	14.2	1.0		5/12/77		14.0	.4	2.4
12/18/76	1315	14.0	1.8	8.2	5/13/77	1430	14.0	.8	2.6
12/21/76	0745	15.6	2.4	6.0	5/14/77	1400	15.0	.4	4.0
01/18/77	1315	14.6	1.2	4.2					
Average							14.42	.90	5.62
Standard Deviation							.89	.58	1.55

shown in Table B-54. The thermal conductivity (TC) gas chromatograph data is shown in Table B-55. The oil and grease (long chain hydrocarbons) analyses are shown in Table B-56.

The kiln crossover duct measurement port is located approximately 1-2 m (3-6 ft) upstream of the point where the crossover combustion air fan and the dust collection fan air enters the duct. The duct itself is a steel sheel 2.1 m (7 ft.) diameter lined with refractory brick 0.115 mm (4.5 in.) thick. The refractory is coated with a slag layer averaging 7.6 cm (3 in.) thick. In the bottom of the duct, the slag has piled up to form a somewhat flat surface having a maximum depth of approximately 0.3 m (1 ft) in the center. In addition, along the wall numerous stalactites and stalagmites combine to form a highly irregular wall surface. This type of deposit, is indicative of highly distorted flow patterns within the crossover duct. For this reason, the flow measurements at this point cannot be relied upon for accuracy. The duct configuration at the crossover measuring station #12 is not ideal for flow measurements for another reason. Immediately downstream of the measurement station gas purifier combustion air enters the duct perpendicularly to the main flow. Flow from these two fans is injected at three points circumferentially around the duct. When the air is injected into the duct perpendicularly to the main flow, the influence of the injected flow is noticeable five to ten duct diameters upstream of the injection point depending upon the flow momentum ratio. In this case, the airflow injected only slightly downstream of a measurement point definitely distort the flow measurement. Although the injection flow distortion is not measured; its influence on measurements is present to some unknown extent and rendors those measurements unreliable.

However, from a statistical aspect, the flow measurement results are consistent and correctable. No conclusion can be made concerning a flow coefficient at this location since this reflects, in effect, a change in flow area. Considering the highly irregular flow surface, no evaluation except on a statistical basis is possible. The gas flow at this point must be determined by summing all of the material inputs into the kiln immediately upstream of the duct.

Gas Purifier Discharge Duct

Gas flow calculations at the gas purifier discharge duct are made in the same manner as those at the kiln crossover duct. The gas purifier duct measurement port is located in a straight section of duct approximately 1-2 m (3-6 ft) long, and having an inside diameter of 2.6 m (8.5 ft). A straight duct section starts at the exit of the gas purifier which has an entrance contraction ratio of 1.63. At the end of the straight duct section, there is a chamber elbow and two quench air ports allowing high rates of flow into the duct. The measurements at this point, therefore, are made immediately downstream of a duct contraction and just prior to an elbow at which point two high flow air masses enter the main duct. As a result, the flow velocity vector cannot be accurately measured due to normal pressure fluctuations which mask the "Peakins" effect of rotating the probe to some offset angle in an attempt to intercept the actual velocity vector. The conclusion

TABLE B-54. FLAME IONIZATION DETECTION ANALYSIS OF CROSSOVER DUCT GASES

Date	Time	Methane ($\mu\text{l/l}$)	Ethane ($\mu\text{l/l}$)	Propane ($\mu\text{l/l}$)	Isobutane ($\mu\text{l/l}$)	N-Butane ($\mu\text{l/l}$)	Acetylene Ethylene* ($\mu\text{l/l}$)
6/30/77	1600	†	†	†	§	-	†
6/30/77	1630	†	134	205	§	123	†
6/30/77	1700	†	144	-	-	-	†
6/30/77	1705	1800	149	246	§	-	813
7/01/77	1300	1970	41	-	-	-	640
7/01/77	1325	†	38	-	-	-	499
7/01/77	1340	†	113	91	§	70	†
7/01/77	1430	2130	-	10	§	10	567
7/01/77	1500	2164	-	27	§	22	591
Average		2020	103	116	§	56	622

* Standard for calibration was run in the lab on 9/22/77. This is a composite number.

† Present.

§ Not detectable.

TABLE B-55. THERMAL CONDUCTIVITY ANALYSIS OF CROSSOVER DUCT GASES

Date	Time	Nitrogen (%)	Carbon Dioxide (%)	Carbon Monoxide (%)	Oxygen (%)	Methane (%)	Hydrogen (%)
8/23/77	1205	61.1	13.3	6.8	1.0	1.24	*
8/23/77	--	--	--	4.8	--	--	*
8/23/77	--	--	--	--	--	0.85	*
8/23/77	1525	--	--	--	--	1.05	*
8/23/77	1540	--	12.5	7.5	--	1.12	*
8/23/77	--	--	9.1	5.5	--	0.70	*
8/23/77	1555	--	12.5	7.9	1.0	0.85	*
8/23/77	1600	--	12.5	7.9	1.0	0.85	*
8/23/77	1610	--	12.5	7.0	1.3	0.85	*
8/23/77	1615	--	12.5	7.9	0.9	1.09	*
8/23/77	1620	--	12.1	7.9	1.3	0.95	*
8/23/77	1705	60.0	--	7.9	1.8	0.89	*
8/23/77	1710	60.0	12.1	8.8	1.2	1.16	*

* Interference, not yet quantified.

TABLE B-56. LONG CHAIN HYDROCARBON ANALYSIS OF CROSSOVER DUCT GASES

Date	Volume of Gas (DSCM)	Total Oil And Grease (mg)	Concentration (mg/DSCM)
6/29/77*	0.75	2,460	3280
6/29/77	0.21	1,566	7483
6/30/77	0.18	1,390	7575

* Bad test (saturated).

again must be that the gas flow measurements at this point are unreliable. Subsequent statistical analysis indicates that the measurements are somewhat consistent though not to the extent noted in the crossover duct. Again, the most reliable flow calculation at this station results from a summation of all input flow upstream of the sampling point.

Again for completeness, the composition data for the gas purifier discharge duct gases are shown in Tables B-57 through B-59. A pilot electrostatic precipitator was tested on the gas purifier discharge duct gases. The gas were first passed through a water quench gas cooler and the results are shown in Table B-60.

Boiler Inlet Duct

While no velocity measurements were possible at this point, facility temperature and orsat measurements were made to aid in the determination of boiler efficiencies. The boiler inlet orsats are shown in Table B-61.

Boiler/Economizer Discharge Duct

Measurement of gas flow at this point is calculated in the same manner as discussed for the kiln crossover and gas purifier exit ducts. The measurement station is located approximately 24 m (78 ft.) downstream of the economizer discharge in a refractory lined section of straight steel wall duct. The straight section is approximately 18.3 m (60 ft) long and has an inner diameter of approximately 2.2 m (7.33 ft). The configuration of this duct, and the low temperature of the gas flow stream (allowing use of a calibrated thermocouple) combine to make this the most ideal gas flow measurement section of those available. Subsequently, experience has shown that measurements agree quite well with flows calculated from measured inputs. This measurement station, therefore, is the only one that can be relied upon as a check on the input flows. The orsat measurements taken at this point are shown in Table B-62. The moisture content of gas at this point was measured and the data is shown in Table B-63. The complete data for the dry electrostatic precipitator tests on the gases at this point is shown in Table B-64. This data was summarized and discussed in the Environmental Assessment Section of Volume II of this report. An ash analysis of the particulate at this point is shown in Table B-65.

TABLE B-57. TOTAL HYDROCARBON ANALYSIS OF GAS PURIFIER EXIT GASES*

Date	Time	Total HC Content As CH ₄ (μl/l)	CH ₄ (μl/l)	CO (μl/l)
3/14/75	0320	3	1	-
3/14/75	0320	8	3	-
3/14/75	1130	16	2	-
4/19/75	-	35	<1	<1
4/10/75	-	128	<1	9

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976, Table 13.

TABLE B-58. MASS SPECTROGRAPHIC ANALYSIS OF GAS PURIFIER EXIT GASES*

Date	4/19/75	4/10/75	4/22/75
Time			0900
	(Vol. %)	(Vol. %)	(Vol. %)
Methane	-	-	Trace
Oxygen	21.00	9.90	13.10
Carbon Dioxide	0.09	10.20	4.60
Hydrogen	-	-	3.10
Ethylene	-	-	-
Acetylene	-	-	-
Ethane	-	-	-
Benzene	-	-	-
Carbon Monoxide	Interference	Interference	1.70
Nitrogen	78.91	79.90	76.70
Argon	-	-	0.80

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976, Table 14.

TABLE B-59. GAS PURIFIER DISCHARGE DUCT ORSATS

DATE	TIME	CO, %	O, %	CO ₂
11/15/76	1230	15.6	3.9	1.5
11/15/76	1545	18.0	0.0	3.3
11/16/76	1420	16.8	2.1	1.8
12/10/76	-	12.6	0.2	1.0
12/13/76	1730	11.4	0.0	1.6
12/21/76	0815	14.0	0.6	0.2
1/18/77	1415	9.4	1.4	3.6
1/13/77	1730	15.2	0.6	0.6
1/15/77	1545	7.0	0.0	7.0
1/20/77	1320	9.2	0.6	2.6
1/31/77	0845	9.8	0.2	1.2
2/ 5/77	1620	11.8	0.2	2.4
2/24/77	1440	4.6	0.0	7.4
5/10/77	1400	15.8	1.2	0.0
5/12/77	1140	14.0	0.2	1.6
5/13/77	1330	14.6	0.0	0.0
5/14/77	1400	16.2	0.0	0.0
6/29/77	0845	9.4	0.2	1.2
6/29/77	1045	13.4	1.2	0.0
6/29/77	1345	17.0	-	-
6/29/77	1420	13.02	0.0	2.2
6/29/77	1645	12.00	0.0	3.6
6/30/77	0845	8.00	-	-
6/30/77	0915	11.20	0.0	2.9
6/30/77	1150	9.20	0.0	5.2
6/30/77	1540	15.80	0.0	0.6
6/30/77	1610	13.80	0.0	0.0
7/ 1/77	1445	14.20	1.8	0.0
Average		12.6	0.30	1.8
Maximum		18.0	3.9	7.4
Minimum		4.6	0.0	0.0

TABLE B-60. ESP RESULTS FOR GAS PURIFIER EXHAUST GASES PASSED THROUGH A GAS COOLER*

DATE	KILN FEED (MG/HR)	TREATMENT ZONE VELOCITY (M/SEC)	INLET/OUTLET % MOISTURE TEMPERATURE BY VOLUME (°C)	INLET LOADING (G/DSCM)	OUTLET LOADING (G/DSCM)	EFFICIENCY (%)	VOLTS (KV)	CURRENT (MA)
8/5/76	18-27	1.0	195/180	2.915	.0526	98.2	55	22
8/5/76	29	1.0	192/179	3.032	.0666	97.8	53	24
8/5/76	27-31	1.0	192/177	3.517	.0575	98.4	53	23
8/5/76	21-28	1.0	192/178	3.705	.0536	98.6	53	23
8/6/76	27-31	.91	192/178	4.048	.0895	97.8	54	23
8/6/76	29	.91	191/179	3.398	.0588	98.3	53	24
8/6/76	28	.91	196/183	3.503	.0843	97.6	53	24
8/6/76	28	.91	196/182	3.741	.0517	98.6	53	24
8/6/76	29	.91	193/181	3.838	.0808	97.9	52	23
8/6/76	27	.91	194/180	4.009	.1259	96.9	52	24
8/7/76	29	.91	195/181	3.492	.0405	98.8	52	24
8/7/76	28	.91	194/180	3.448	.0489	98.6	51	24
8/7/76	28	.91	194/176	3.054	.0742	97.6	52	24
8/7/76	30	.91	194/179	3.208	.0334	98.9	53	23

* White, S. J., Jr., Environmental Elements Corporation. Precipitator Application Survey City of Baltimore Pyrolysis Plant. No. 7364. Baltimore, Maryland, 1976. p. v:10, 10/20/76.

TABLE B-61. BOILER INLET ORSATS

DATE	TIME	CO ₂ %	O ₂ %	CO%
12/09/76	1915	11.0	7.0	0.0
12/12/76	1400	10.0	6.2	0.0
12/21/76	0845	5.4	11.6	0.0
1/15/77	1657	7.8	9.6	0.4
1/18/77	1445	10.6	4.0	0.0
1/23/77	1445	8.4	10.0	0.0
1/31/77	0935	5.8	12.6	0.0
2/05/77	1615	9.0	--	--
AVERAGE				
		8.5	8.7	0.0
MAXIMUM		11.0	11.6	0.4
MINIMUM		5.4	4.0	0.0

TABLE B-62. BOILER OUTLET ORSATS

DATE	TIME	CO ₂ %	O ₂ %	CO%
12/07/76	1815	9.0	9.5	0.0
1/05/77	1720	8.4	10.4	0.0
1/18/77	1520	7.8	11.0	0.0
5/06/77	1530	7.8	8.0	1.6
5/10/77	1400	7.6	4.2	2.8
5/12/77	1100	9.2	4.2	4.4
5/13/77	1100	9.0	7.4	1.0
5/14/77	1400	8.0	10.8	0.0
6/29/77	0845	9.4	9.8	0.0
6/29/77	1045	8.4	9.4	0.0
6/29/77	1420	8.2	11.2	0.0
6/29/77	0915	7.4	12.2	0.0
6/30/77	1130	8.6	10.8	0.0
6/30/77	1150	7.6	10.6	0.0
6/30/77	1540	9.0	8.8	0.0
7/01/77	0930	6.0	12.6	0.2
7/01/77	1445	6.8	11.0	0.6
AVERAGE		8.1	9.5	0.6
MAXIMUM		9.4	12.6	4.4
MINIMUM		6.0	4.2	0.0

TABLE B-63. MOISTURE CONTENT OF BOILER EXIT GASES

DATE	KILN FEED (Mg/hr.)	Moisture (% Volume)
6/14/76*	32.7	15.5
6/14/76*	25.0	20.5
6/22/76*	27.2	18.5
6/22/76*	27.2	17.2
6/22/76*	25.4-29.9	21.3
6/22/76*	25.0-27.2	23.8
6/22/76*	29.0	23.4
6/23/76*	27.2-39.0-30.8	21.4
6/23/76*	38.1-25.4-29.9	21.7
6/23/76*	20.9-25.0	19.6
6/25/76*	28.1-0	20.7
7/21/76*	36.3-26.3	18.8
7/21/76*	28.1	21.5
7/21/76*	28.1	22.2
7/21/76*	28.1	25.0
7/22/76*	27.2	23.8
7/22/76*	27.2	21.9
7/22/76*	28.1	21.7
7/22/76*	27.2	21.9
7/23/76*	35.4	21.0
7/23/76*	36.3	21.4
7/23/76*	33.6	23.2
7/23/76*	39.0	22.0
7/24/76*	36.3	23.7
7/24/76*	34.5	23.9
7/24/76*	34.5-41.7	23.3
7/26/76*	35.4	20.7
7/26/76*	29.0-38.1	22.1
7/26/76*	34.5	23.6
7/26/76*	38.1	21.5
7/26/76*	37.2	21.6
7/27/76*	27.2	19.9
7/27/76*	30.8	21.5
7/27/76*	32.7	21.4
7/27/76*	31.8	22.7
7/28/76*	35.0-45.4-0	19.7
8/05/76*	35.0	16.3
8/05/76*	33.6	17.2
8/05/76*	31.8	18.4
6/30/77		10.4
6/30/77		12.1
6/30/77		12.0
AVERAGE		20.5

* White, S. J., Jr., Environmental Elements Corporation. Precipitator Application Survey City of Baltimore Pyrolysis Plant. No. 7364. Baltimore, Maryland, 1976. pp. V9, V10.

TABLE B-64. DRY ESP TEST OF BOILER EXIT GASES*

DATE	KILN FEED (MG/HR)	TREATMENT ZONE VELOCITY (M/SEC)	INLET/OUTLET % MOISTURE TEMPERATURE (°C)	INLET LOADING (g/DSCM)	OUTLET LOADING (g/DSCM)	EFFICIENCY (%)	VOLTS (KV)	CURRENT (MA)
6/14/76	32.7	1.28	152/144	--	--	--	48	15
6/14/76	25.0	1.19	154/144	.7405	.1106	85.1	54	13
6/22/76	27.2	1.28	160/143	.5021	.1181	76.5	52	14
6/22/76	27.2	1.25	170/156	.4845	.1076	77.8	48	15
6/22/76	25.4-29.9	1.22	174/160	.6182	.0545	91.2	50	15
6/22/76	25.0-27.2	1.22	190/165	.4032	.0632	84.3	48	16
6/22/76	29.0	1.31	176/159	4.9231	.1662	96.6	54	14
6/23/76	27.0-39.0-30.8	.88	171/141	.5053	.0467	90.8	48	14
6/23/76	38.1-25.4-29.9	.94	182/171	.4154	--	--	48	16
6/23/76	20.9-25.0	.94	194/176	1.1378	.0591	94.8	46	16
6/25/76	28.1- 0.0	.91	149/136	.4522	.0414	90.8	49	14
7/21/76	36.3-26.3	.64	194/170	.5024	.0586	88.3	48	16
7/21/76	28.1	.64	182/163	.4419	.0339	92.3	49	15
7/21/76	28.1	.64	185/166	.4545	.0504	88.9	49	15
7/21/76	28.1	.64	194/171	.5898	.0410	93.1	49	15
7/22/76	27.2	.67	193/172	.4685	.0437	90.7	50	15
7/22/76	27.2	.67	190/170	.6729	.0378	94.4	50	15
7/22/76	28.1	.67	175/159	.6478	.0586	91.0	47	18
7/22/76	27.2	.67	182/164	.5305	.0524	90.1	47	18
7/23/76	35.4	.67	203/172	.6292	.0325	94.8	43	23
7/23/76	36.3	.67	212/183	.5553	.0188	96.6	43	23
7/23/76	33.6	.67	207/183	3.8522	.0307	99.2	43	22
7/23/76	39.0	.67	192/170	.5266	.0444	91.6	46	19
7/24/76	36.3	.94	194/174	.4172	.0387	90.7	44	22
7/24/76	34.5	.91	204/185	5.4873	.0373	99.3	45	19
7/24/76	34.5-41.7	.94	170/159	.3819	.0341	91.1	49	14
7/26/76	32.7- 0.0	.91	181/161	.8280	.1365	83.5	47	16
7/26/76	35.4	.91	183/162	.6842	.0637	90.7	47	16
7/26/76	29.0-38.1	.91	184/172	3.4783	.0872	97.5	50	12

(continued)

TABLE B-64. (Continued)

DATE	KILN FEED (Mg/HR)	TREATMENT ZONE VELOCITY (M/SEC)	INLET/OUTLET % MOISTURE TEMPERATURE BY VOLUME (°C)	INLET LOADING (g/DSCM)	OUTLET LOADING (g/DSCM)	EFFICIENCY (%)	VOLTS (KV)	CURRENT (MA)
7/26/76	34.5	.91	186/167	.5692	.0504	91.2	46	16
7/26/76	38.1	.91	206/182	3.2550	.0506	98.4	45	20
7/26/76	37.2	.61	216/189	.6681	.0247	96.2	45	21
7/27/76	27.2	.91	175/159	.5873	.0627	89.3	47	17
7/27/76	30.8	.91	179/166	2.1681	.1012	95.3	50	14
7/27/76	32.7	.91	181/160	.6106	.0756	87.6	49	15
7/27/76	31.8	.91	190/174	.5997	.0600	90.0	48	16
7/28/76	35.0-45.4-0	.91	171/159	.7409	.0646	91.3	47	16
8/ 5/76	35.0	.91	182/157	.4877	.0804	83.6	47	15
8/ 5/76	33.6	.91	197/175	.6045	.0504	91.7	44	19
8/ 5/76	31.8	.91	190/176	3.5078	.0746	97.9	45	15

* White, S. J., Jr., Environmental Elements Corporation. Precipitator Application Survey City of Baltimore Pyrolysis Plant. No. 7364. Baltimore, Maryland, 1976. pp. V9, V10.

TABLE B-65. ASH ANALYSIS OF BOILER EXIT GAS PARTICULATE*

DATE	6/15	6/24	7/22	7/22	7/27	7/28
COMPONENT	% BY WEIGHT					
Alumina	11.84	16.78	16.05	12.18	11.45	7.22
Calcium Oxide	4.99	13.16	13.70	5.38	8.38	6.38
Ferric Oxide	5.36	6.37	4.57	1.61	3.12	1.51
Lithium Oxide	0.40	0.30	0.47	0.72	0.22	0.30
Magnesium Oxide	0.45	3.56	3.81	0.25	2.74	2.50
Potassium Monoxide	6.25	6.25	6.32	9.60	4.08	8.00
Silicon Dioxide	12.47	36.61	38.82	8.50	24.60	13.90
Sodium Monoxide	16.88	13.50	13.20	16.20	8.59	14.55
Sulfur Trioxide	10.17	6.38	8.18	6.68	8.83	8.93
Titanium Dioxide	1.62	3.42	2.98	1.27	2.13	1.59
Lost on Ignition	29.24	22.39	23.81	37.41	25.85	34.96
MASS MEDIAN PARTICLE SIZE (MICRONS)	6	8	10	4	16	11

* White, S. J., Jr., Environmental Elements Corporation. Precipitator Application Survey City of Baltimore Pyrolysis Plant. No. 7364. Baltimore, Maryland, 1976. pp. VI 1.

CHARACTERIZATION OF SOLID MATERIAL STREAMS

Refuse

Since the composition of the refuse was discussed previously only the refuse feed rates requires further discussion. The refuse feed rate to the kiln was normally determined by the belt scale on the kiln feed conveyor. However, during most of the Systech test, the storage and recovery unit was bypassed, thereby bypassing the belt scale. As a result, only one test was taken when the refuse feed rate was measured by the belt scale. For all other tests the flow rate was estimated based upon the average shredding rate of 27 Mg/hr (30 tph), and the level of the refuse on the conveyors. The energy flow rates for the refuse was determined by multiplying the mass flow rate by the heat of combustion of the refuse (Table B-19).

Kiln Residue

Kiln residue mass flow rate measurements were made on an intermittent basis. The total residue weight for a known period of time was measured and compared to the total refuse input weight during the corresponding time period. The residue flow rate was calculated as a percentage of the refuse feed rate on a wet basis (Table B-66). This percentage varies considerably with the degree of processing. At one point when all the char was being combusted the percentage was much lower (Table B-67).

The moisture content of the residue was measured daily on site using a drying oven at 103°C (217°F). The moisture content was inversely dependent upon the degree of refuse processing. The moisture content data is shown in Table B-68. The average moisture content of 31 percent was used to calculate the residue flow rate on a dry basis as it comes out of the kiln. Multiplying the wet flow percentage by the solids content (1 - moisture content) the dry kiln residue discharge is 30 percent of the incoming refuse.

The bulk density of the refuse was measured by weighing a known volume of residue. This data is also shown in Table B-68.

Proximate analyses (Table B-69) of numerous residue samples were conducted both by Monsanto and SYSTECH. All SYSTECH data was corrected to reflect the moisture content measured on-site, and all data was corrected to reflect unshreddable materials which were separated from the sample. These separated materials were included as ash. The heat output rate due to the heat of combustion of the char in the residue was then calculated by multiplying the mass rate by the heat content (Table B-69).

Ultimate analysis of the residue is shown in Table B-70 and ash analysis of the residue is shown in Table B-71. This data was used to determine the specific heat of the residue and thereby the sensible heat loss due to the residue discharge. This loss is calculated by multiplying the mass rate by the specific heat and a temperature differential. The specific heat, (estimated to be .33 cal/g°C) was calculated as a weighted average of the component specific heats. The component percentages were obtained from the proximate (Table B-69) and ash analyses (B-71), while the component specific

TABLE B-66. RESIDUE WEIGHT CALCULATIONS

Date	Time		Refuse (kg)	Residue (kg)	%
	Start	Stop			
12/22/76	1547	2129	110934	41484	37
2/ 3/77	1400	1745	54109	21013	39
2/ 3/77	2005	2310	97067	46682	48
3/17/77	1602	2122	135318	64650	48
Total			397429	173830	44

TABLE B-67. RESIDUE WEIGHT CALCULATIONS*

Date	Time		Refuse (kg)	Residue (kg)	%
	Start	Stop			
3/14/77	1708	2300	144045	46095	32
3/15/77	1555	2205	155545	49136	32
3/16/77	1526	1646	37727	14309	38
Total			337318	109541	32.5

*No Char

TABLE B-68. RESIDUE MOISTURE CONTENT AND BULK DENSITY

Date	Moisture (%)	Bulk Density (kg/m ³)	Date	Moisture (%)	Bulk Density (kg/m ³)
11/ 8/76	33	1169	2/ 4/77	33	1554
11/12/76	22	1522	2/ 5/77	22	
11/15/76	28	1778	2/ 6/77	22	
11/16/76	15	1650	2/22/77	36	1746
11/17/76	14	1474	2/25/77	74	
11/29/76	21	2275	2/28/77	21	2162
12/ 7/76	21	1426	3/ 8/77	21	1378
12/ 9/76	39	1185	3/ 9/77	37	1474
12/10/76	34	1938	3/11/77	25	2210
12/12/76	33	1842	3/14/77	16	1378
12/13/76	52	1586	3/15/77	16	1217
12/14/76	30	1602	3/17/77	30	1297
12/16/76	31	1842	3/27/77	47	
12/17/76	32	1842	4/28/77	75	1041
12/18/76	26	1762	4/29/77	26	1586
12/21/76	24	1986	5/ 2/77	44	1286
1/18/77	36	1698	5/ 3/77	29	1586
1/19/77	25	1986	5/ 5/77	31	1474
1/20/77	32	1778	5/ 6/77	27	1938
1/23/77	19	1314	5/ 9/77	49	1474
1/24/77	33	1922	5/10/77	38	1682
1/31/77	24	1506	5/11/77	28	1458
2/ 1/77	23	1618	5/12/77	24	1510
2/ 3/77	25	1874	5/13/77	27	
%Moisture			Bulk Density		
Average		30.6	Average		1,630.0
Standard Deviation		12.4	Standard Deviation		282.7

TABLE B-69. PROXIMATE ANALYSIS OF RESIDUE.

DATE TIME	3/13/75† 0800	3/13/75† 0830	3/13/75† 0900	3/13/75† 0930
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	32.48	-	21.76
Volatile Matter	%	4.87	7.22	20.26
Fixed Carbon	%	3.88	5.75	3.54
Ash	%	58.76	87.02	1.52
Sulfur	%	0.14	0.20	74.68
Heat Content	MJ/kg	1.76	2.61	-
Total Separated Matter	*%	-	0.79	-
			0.67	-
			1.46	-
			-	24.60
DATE TIME	3/13/75† 1000	3/13/75† 1405	3/13/75† 1452	3/13/75† 1530
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	26.37	-	10.92
Volatile Matter	%	2.25	3.05	18.13
Fixed Carbon	%	1.68	2.28	2.93
Ash	%	69.71	94.68	0.31
Sulfur	%	-	-	78.63
Heat Content	MJ/kg	-	15.37	-
Total Separated Matter	*%	-	2.00	-
			10.64	-
			-	9.21

(continued)

TABLE B-69. (Continued)

DATE TIME	3/13/75† 1630	3/13/75† 1830	3/14/75† 0330	3/14/75† 0430
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	8.99	7.87	43.98
Volatile Matter	%	2.86	1.26	6.72
Fixed Carbon	%	0.24	0.09	6.04
Ash	%	87.91	90.77	43.26
Sulfur	%			0.11
Heat Content	MJ/kg			0.20
Total Separated Matter	*%	11.88	24.08	6.00
				20.32
				32.50
DATE TIME	3/14/75† 0500	3/14/75† 0535	3/14/75† 0600	3/14/75† 0630
	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	50.66	29.33	51.66
Volatile Matter	%	5.25	4.39	5.13
Fixed Carbon	%	5.65	2.30	4.45
Ash	%	38.44	63.98	38.76
Sulfur	%	0.08	0.08	0.09
Heat Content	MJ/kg	2.99	0.64	2.60
Total Separated Matter	*%	17.97	26.38	24.47
				23.56

(continued)

TABLE B-69. (Continued)

DATE TIME	3/14/75† 1030	3/14/75† 1100	3/25/75† COMPOSITE	3/31/75† 2300
	AS REC'D	DRY	AS REC'D	DRY
Moisture	% 18.89	-	17.51	-
Volatile Matter	% 2.17	2.67	2.25	7.74
Fixed Carbon	% 1.56	1.92	.68	8.52
Ash	% 77.38	95.41	79.56	83.75
Sulfur	%			0.14
Heat Content	MJ/kg			4.71
Total Separated Matter	%	12.24	25.18	10.64
				48.81
				4.45
				6.42
				40.32
				0.12
				2.86
				-
				1.60

DATE TIME	4/ 1/75† 0100	4/10/75† 0320	4/13/75† 1900	4/22/75† 1000
	AS REC'D	DRY	AS REC'D	DRY
Moisture	% 43.19	-	26.10	-
Volatile Matter	% 3.74	6.59	6.80	10.02
Fixed Carbon	% 3.99	7.03	5.36	13.25
Ash	% 49.08	86.39	61.74	76.73
Sulfur	% 0.01	0.01	0.14	0.12
Heat Content	MJ/kg	2.91	3.78	5.81
Total Separated Matter	%	3.72	-	-
				26.00
				3.15
				5.28
				65.58
				0.09
				0.91
				2.26
				-
				4.26
				7.14
				88.62
				0.12
				1.23
				-

(continued)

TABLE B-69. (Continued)

[illegible]

(continued)

TABLE B-69. (Continued)

DATE TIME	11/15/76-11/21/76 COMPOSITE		12/12/76-12/18/76 COMPOSITE		1/16/77-1/22/77 COMPOSITE		2/1/77-2/5/77 COMPOSITE	
	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY
Moisture	%	19.00	-	34.00	-	31.00	25.75	-
Volatile Matter	%	1.38	1.70	3.47	5.26	0.00	0.34	0.46
Fixed Carbon	%	4.29	5.30	0.77	1.16	8.94	3.42	4.61
Ash	%	75.33	93.00	61.76	93.58	60.06	70.49	94.93
Sulfur	%	0.22	0.27	0.17	0.25	0.17	0.13	0.17
Heat Content	MJ/kg	1.92	2.37	0.81	1.22	2.98	1.25	1.69
Total Separated	*%	-	-	-	4.37	-	-	7.95

* Included as ash.

† Herrington, R. D., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 37.

‡ Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 19.

¶ Moisture corrected to moisture content measured on site.

TABLE B-70. ULTIMATE ANALYSIS OF RESIDUE

DATE TIME	6/20/76* 0400	6/21/75* 0845	8/07/76† 1400	11/15/76-11/21/76 COMPOSITE	12/12/76-12/18/76 COMPOSITE
Carbon %	15.48	3.16	3.00	5.57	3.63
Hydrogen %	0.35	0.08	0.19	0.34	0.33
Nitrogen %	1.23	.39	0.07	0.23	0.11
Oxygen %	1.55	1.24	0.43	0.59	2.08

DATE TIME	1/16/77-1/22/77 COMPOSITE	2/1/77-2/5/77 COMPOSITE
Carbon %	12.66	4.49
Hydrogen %	<0.09	0.10
Nitrogen %	0.47	0.11
Oxygen %	<0.09	0.19

* Herrington, R. D., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 37.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 19.

TABLE B-71. ASH ANALYSIS OF RESIDUE

DATE TIME	11/15/76-11/21/76 COMPOSITE	12/12/76-12/18/76 COMPOSITE	1/16/77-1/22/77 COMPOSITE	2/1/77-2/5/77 COMPOSITE
	%	%	%	%
Alumina	4.61	3.09	4.91	2.58
Ferric Oxide	7.87	1.91	1.61	43.58
Lime	5.40	6.15	2.89	5.44
Magnesia	0.85	0.73	0.46	0.72
Phosphorous Pentoxide	0.80	0.89	0.30	0.51
Potassium Oxide	0.29	0.43	0.74	0.61
Silica	68.30	75.40	68.23	38.76
Sodium Oxide	4.92	6.04	12.12	3.82
Sulfur Trioxide	0.58	0.55	0.51	0.54
Titania	2.03	0.28	0.18	0.50

	MINIMUM %	AVERAGE %	MAXIMUM %
Alumina	2.58	3.80	4.91
Ferric Oxide	1.61	13.74	43.58
Lime	2.89	4.97	6.15
Magnesia	0.46	0.69	0.85
Phosphorous Pentoxide	0.30	0.63	0.89
Potassium Oxide	0.29	0.52	0.74
Silica	38.76	62.67	75.40
Sodium Oxide	3.82	6.73	12.12
Sulfur Trioxide	0.51	0.55	0.58
Titania	0.18	0.75	2.03

heats were typical handbook values. The temperature differential is the difference between the residue temperature, as measured by the optical pyrometer, and the reference temperature 273°K.

Table B-72 presents all the residue size data discussed previously in Volume II of this report.

Tables B-73 and B-74 present the refuse and residue ash fusion temperature data respectively. These tables should be and are very similar.

The gasoline consumption was discussed previously in the Mass and Energy Balance Section of Volume II. The complete data is presented in Tables B-75 and B-76.

The residue quench tank process water and the residue truck drainage were summarized and discussed in the Environmental Assessment Section of Volume II. The complete data is presented in Tables B-77 and B-78.

Gas Purifier Slag and Kiln Spillback

Because of the continuous seal tank and the single transfer screw conveyor only the combined spillage and slag flow rates could be measured normally. On one occasion when the slag tap hole plugged, the spillage flow was estimated to be less than 0.5 kg/min. (1.1 lbs./min.) or 0.13 percent of the input refuse flow which is insignificant. Therefore, most of the flow is slag, and all will be considered as such.

Unlike residue, the city records the weight of all the slag discharged continuously. When this data is compared to the total refuse input over the same time period, the slag flow, as a percentage of refuse input, can be calculated (Table B-79).

In order to calculate the amount of slag discharged from the gas purifier before it enters the water quench the moisture content must be known. The moisture content was measured on-site similarly to the kiln residue. Using the average wet slag flow percentage of 1.77 (Table B-79) and the average moisture content of 14 percent (Table B-80) the average dry slag flow percentage is 1.52 percent. The slag bulk density was measured similarly to the kiln residue and the data is presented in Table B-80.

The ash analyses of the gas purifier slag are shown in Table B-81. It should be noted that the blue and grey slag are not included in the average. These are separate because they are samples of the slag that were found in the sealed slag tap hole. The grey slag with the high alumina and low silica percentages caused most of the slag hole plugging. The ash analyses were used to determine the composite specific heat of the slag by the same method used to calculate the kiln residue specific heat. The specific heat of the slag was estimated to be 0.4 cal./g°C. The temperature differential for the sensible heat loss by the slag was calculated using the gas temperature in the gas purifier and the reference temperature of 273°K.

TABLE B-72. RESIDUE SIZE DISTRIBUTION

Date	2/4/77	3/11/77	3/18/77	5/6/77	5/13/77	Average
Size (mm)	Weight (Grams)					Weight %
SIZE>152.4						
101.6<SIZE<152.4	91	319	161	19		3
50.8<SIZE<101.6	454	483	593	286	468	10
24.4<SIZE<50.8	454	90	237	295	191	6
5.1<SIZE<25.4	1362	590	580	617	905	19
SIZE<5.1	5448	1827	3296	963	2122	62

TABLE B-73. REFUSE ASH FUSION TEMPERATURES (°C)

Date	11/15-12/76	12/12-18/76	1/16-22/77	2/1-5/77	Average
Initial Deformation	1004	1093	1066	1004	1042
Softening Temperature	1037	1127	1104	1038	1076
Hemispherical Temperature	1060	1171	1149	1054	1108
Fluid Temperature	1093	1204	1177	1093	1142

TABLE B-74. RESIDUE ASH FUSION TEMPERATURES (°C)

Date	11/15-12/76	12/12-18/76	1/16-22/77	2/1-5/77	Average
Initial Deformation	982	988	1066	982	1004
Softening Temperature	1021	1016	1104	1015	1039
Hemispherical Temperature	1043	1038	1149	1037	1067
Fluid Temperature	1071	1060	1177	1077	1096

TABLE B-75. GASOLINE CONSUMPTION WHILE PROCESSING*

PERIOD	DAYS	REFUSE PROCESSED (Mg)	TOTAL CONSUMPTION (LITERS)	CONSUMPTION PER Mg (LITERS/MG)	CONSUMPTION PER DAY (LITERS/DAY)
11/ 6/76-11/ 7/76	2	299	840	2.8	420
11/12/76-11/16/76	5	2,560	3,172	1.2	634
11/25/76-11/29/76	5	1,751	2,373	1.4	475
12, 7/76-12/19/76	13	5,365	8,135	1.5	626
1/ 8/77- 1/24/77	17	5,817	11,587	2.0	682
1/31/77- 2/ 6/77	7	3,341	5,512	1.6	787
2/22/77- 3/17/77	24	10,560	13,612	1.3	567
TOTAL	73	29,693	45,232	1.52	620

*City Daily Log

TABLE B-76. GASOLINE CONSUMPTION DURING DOWNTIME*

PERIOD	DAYS	TOTAL CONSUMPTION (LITERS)	CONSUMPTION PER DAY (LITERS/DAY)
11/ 4/76-11/ 5/76	2	8	4
11/19/76-11/24/76	6	609	101
11/30/76-12/ 3/76	4	481	120
12/24/76- 1/ 7/76	15	1,889	126
1/25/77- 1/27/77	3	310	103
2/10/77- 2/21/77	12	609	51
TOTAL	42	3,907	93

*City Daily Log

TABLE B-77. ANALYSIS OF RESIDUE QUENCH TANK PROCESS WATER

DATE		2/1/77	3/1/77	4/29/77	AVERAGE
pH		9.7	-	9.6	9.7
Alkalinity	(mg/l)	680	800	530	670
BOD ₅	(mg/l)	-	48	1020	534
COD	(mg/l)	-	9200	3440	6320
Suspended Solids	(mg/l)	-	8830	6700	7765
Total Solids	(mg/l)	-	13500	10300	11900
Volatile Solids	(mg/l)	-	4670	4450	4560
Volatile Suspended Solids	(mg/l)	-	985	2320	1653
Iron	(mg/l)	-	98	67	82
TKN	(mg/l)	-	0.9	-	0.9
Total Phosphorous	(mg/l)	16.2	15.2	-	15.7
Standard Plate Count (Organism/ml)		0	45	77	41
Total Coliform	(MPN/ml)	-	0	0	0
Fecal Streptococci	(MPN/ml)	-	210	0	105
Lead	(mg/l)	-	-	70	70
Mercury	(mg/l)	-	-	0.019	0.019

TABLE B-78. ANALYSIS OF RESIDUE TRUCK DRAINAGE

Date		3/1/77	4/29/77	Average
pH	(mg/l)	-	10.3	10.3
Alkalinity	(mg/l)	276	350	313
Acidity	(mg/l)	-	-	-
BOD ₅	(mg/l)	53	1200	626
COD	(mg/l)	596	2570	1583
Chlorides	(mg/l)	3890	2540	3207
Suspended Solids	(mg/l)	315	675	495
Total Solids	(mg/l)	10200	7580	8890
Volatile Solids	(mg/l)	7176	1880	4528
Volatile Suspended Solids	(mg/l)	111	435	273
Hardness	(mg/l)	-	-	-
Sulfide	(mg/l)	-	-	-
Sulfite	(mg/l)	-	-	-
Sulfate	(mg/l)	-	-	-
Iron	(mg/l)	2.1	800	401
TKN	(mg/l)	5.3	-	5.3
Total Phosphorous	(mg/l)	0.47	-	0.47
Standard Plate Count	(Organism/ml)	16	74000	37000
Total Coliform	(MPN/ml)	0	0	0
Fecal Streptococci	(MPN/ml)	17	5	11
Lead	(mg/l)	0.7	0.8	.75
Mercury	(mg/l)	0.001	0.008	.004

TABLE B-79. SLAG WEIGHT CALCULATIONS

Period	Refuse Mg.	Slag Mg.	Weight %
11/ 7/76-11/ 9/76	593.90	8.13	1.4
11/26/76-11/30/76	1872.67	36.85	1.9
12/ 7/76	599.58	7.45	1.2
12/10/76-12/27/76	6616.81	120.54	1.8
1/ 8/77- 1/25/77	5921.54	99.91	1.7
2/ 3/77- 2/ 7/77	2182.39	26.90	1.2
2/22/77- 3/17/77	10561.00	182.23	1.7
4/25/77- 5/15/77	10563.00	197.04	1.8
Total	38344.72	679.05	1.77

TABLE B-80. SLAG MOISTURE CONTENT AND BULK DENSITY*

Date	Moisture Content (%)	Bulk Density (kg/m ³)	Date	Moisture Content (%)	Bulk Density (kg/m ³)
11/08/76	5	1602	2/01/77	9	1569
11/12/76	11	1362	2/03/77	13	1650
11/15/76	12	1730	2/04/77	8	1442
11/16/76	10	1490	2/22/77	12	2066
11/17/76	20		2/28/77	11	2082
11/29/76	12	1666	3/08/77	16	1570
12/07/76	47	1842	3/09/77	10	1954
12/09/76	32	1954	3/11/77	12	1826
12/10/76	12	1217	3/14/77	13	1538
12/12/76	21	2002	3/15/77	10	1426
12/13/76	8	1650	4/27/77	8	1666
12/14/76	10	1650	4/28/77	9	1544
12/16/76	9	1650	4/29/77	14	2018
12/17/76	18	1602	5/02/77	11	1698
12/18/76	12	1698	5/03/77	12	1394
12/19/76	23	1794	5/04/77		1506
12/21/76	14	1922	5/05/77	7	1906
01/18/77	15	1586	5/06/77	9	1986
01/19/77	25	1922	5/09/77	11	1714
01/20/77	22	1330	5/10/77	14	1842
01/23/77	14	1730	5/11/77	18	1153
01/24/77	13	2130	5/12/77	13	1490
			Minimum	7	1153
			Maximum	47	2130
			Average	14	1690

TABLE B-81. ASH ANALYSIS OF GAS PURIFIER SLAG

Date	5/13/76*	5/13/76*	5/13/76*	6/9/76†	12/12-18/76	12/19-23/76	1/16-22/76	2/1-5/76
Time				0130	COMPOSITE	COMPOSITE	COMPOSITE	COMPOSITE
Color	GREY	BLACK	BLUE	BLACK	BLACK	BLACK	BLACK	BLACK
Component	PERCENT BY WEIGHT							
Alumina	23.50	12.10	14.20	11.50	18.00	13.50	15.90	19.80
Carbon	0.22	0.14	0.06	1.78				15.13
Chromic Oxide	0.04	0.04	0.04	0.05				0.10
Ferric Oxide	3.30	3.20	3.30	3.00	4.99	3.35	3.21	3.64
Lime	11.50	10.10	9.70	11.40	8.74	8.80	7.20	3.57
Magnesia	2.30	2.10	2.00	2.20	1.67	1.72	1.51	9.22
Nickel Oxide	0.08	0.08	0.07					1.83
Phosphorous								0.06
Pentoxide					2.90	2.00	2.55	1.64
Potassium Oxide	1.60	1.80	1.60	1.60	0.94	3.24	0.84	0.91
Silica	48.10	60.20	58.30	57.90	53.00	53.10	60.00	51.65
Sodium Oxide	4.90	6.70	6.40	6.50	0.54	5.81	3.78	3.64
Stannic Oxide	0.16	0.29	0.13	0.16				4.50
Sulfur Trioxide					0.20	0.15	0.18	0.23
Titania	2.30	1.60	1.60	1.80	3.04	2.40	2.26	0.16
Zinc Oxide	0.53	0.36	0.39	0.32				2.38
								0.34

*Herrington, R.C., T.F. Buss, and D.E. Honaker, Baltimore Landgard® Process Characterization. Monsanto
EnviroChem Systems, Inc., No. 7250, St. Louis, Missouri, 1976, Table 4,

†Herrington, R.F., T.F. Buss, and D.E. Honaker, Baltimore Landgard® Process Characterization. Monsanto
EnviroChem Systems, Inc., No. 7250, St. Louis, Missouri, 1976, Table 5,

The size distribution of the gas purifier slag is shown in Table B-82. Table B-83 presents all the slag ash fusion temperature data. Table B-84 is the complete data set of the slag quench tank process water which was summarized and discussed in the Environmental Assessment Section of Volume II of this report.

Boiler Fly Ash

Most of the boiler fly ash data was presented and discussed in the Environmental Assessment section of Volume II of this report. The fly ash mass flow rate was calculated using the same technique as the kiln residue and the gas purifier slag (Table B-85). The ash fusion temperature data for the boiler fly ash is presented in Table B-86.

QUENCH WATER VAPORIZATION

No direct measurement of the quantity of water vaporized from the residue quench and seal tanks to the process gas flow was possible. Overall water flow to the tanks was measured periodically, but this also includes water removed with the residue and slag. Since both the slag and residue were analyzed for moisture content, the quantity of water removed with the residue and slag was subtracted from the total flow to the tanks to calculate an estimated average water vaporization rate for each. The actual flow rate varies with gas temperature, and, in the case of the seal tank, the amount of slag tap hole plugging which has occurred to reduce the flow of heat into the tank from the process. The average flow rate of water vapor entering the kiln from the residue and spillback quench water was estimated to be 4.5 kg (10 lbs) per minute. The slag quench water vaporization into the gas purifier had an estimated average between 2.3 and 4.5 kg (5 and 10 lbs) per minute.

The quench water vaporized has absorbed heat from the kiln and the gas purifier, respectively. The heat used to vaporize the water is returned to the process as the water vaporizes with an additional input of the sensible heat of the supply water. Therefore, the sensible heat input is calculated by multiplying the mass input rate by the enthalpy of the cold water.

BOILER WATER INPUTS AND OUTPUTS

Cold Water Supply

While instantaneous supply water flow measurements were made, the more reliable differential readings of the totalizers on the softeners was used to determine boiler feedwater flow rates.

The cold water heat content was calculated by multiplying the mass flow rate by the enthalpy of the softened water before the deaerating heater. The heat added in the deaerating heater is closed looped within the boiler system.

TABLE B-82. SLAG SIZE DISTRIBUTION

Size (mm)	Weight (%)								Average
	11/29/76	12/7/76	1/23/77	3/11/77	3/18/77	5/6/77	5/13/77		
5.08 < Size < 101.6	0	0	0	0	5	0	0		1
25.4 < Size < 50.8	0	5	0	0	0	0	0		1
5.1 < Size < 25.4	6	55	11	14	7	13	15		17
Size < 5.1	94	40	89	86	88	87	85		81

TABLE B-83. SLAG ASH FUSION TEMPERATURES (°C)

Date Time Color	*		*		6/20/75*	
	Blue		Grey		1500 Black	
	Reducing	Oxidizing	Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation	1065	1116	1038	1110	1038	1099
Softening	1121	1166	1121	1171	1132	1177
Hemispherical	1138	1188	1138	1193	1154	1204
Fluid	1177	1227	1171	1221	1371	1443

Date Time Color	6/21/75*		5/13/76†		5/13/76†	
	0800 Black		Grey		Black	
	Reducing	Oxidizing	Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation	1071	1110				
Softening	1154	1182				
Hemispherical	1177	1204				
Fluid	1343	1360		<1480		1398

Date Time Color	5/13/76†		1/16/77 - 1/22/77		2/1/77 - 2/5/77	
	Black		Black		Black	
	Reducing	Oxidizing	Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation			1188	1271	1010	
Softening			1210	1299	1038	
Hemispherical			1238	1321	1082	
Fluid		1398	1287	1366	1132	

(continued)

TABLE B-83. (Continued)

Date Time Color	12/19/76 - 12/23/76		1/16/77 - 1/22/77		2/1/77 - 2/5/77	
	Reducing	Oxidizing	Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation	<982		<982		<982	
Softening	<982		<982		<982	
Hemispherical	1010		1021		1010	
Fluid	1066		1066		1066	
*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976, Table 39.						
†Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976, Table 4.						
§Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976, Table 5.						

TABLE B-84. ANALYSIS OF SLAG QUENCH TANK PROCESS WATER

DATE		2/1/77	3/1/77	4/29/77	AVERAGE
pH	(mg/l)	10.1	-	9.4	9.7
Alkalinity	(mg/l)	100	116	66	94
Acidity	(mg/l)	-	-	-	-
BOD ₅	(mg/l)	-	8	24	16
COD	(mg/l)	-	179	340	260
Chlorides	(mg/l)	-	-	-	-
Suspended Solids	(mg/l)	-	187	356	272
Total Solids	(mg/l)	-	708	856	782
Volatile Solids	(mg/l)	-	496	277	386
Volatile Suspended Solids	(mg/l)	-	76	108	92
Hardness	(mg/l)	-	-	-	-
Sulfide	(mg/l)	-	-	-	-
Sulfite	(mg/l)	-	-	-	-
Sulfate	(mg/l)	-	-	-	-
Iron	(mg/l)	-	-	7.0	7.0
TKN	(mg/l)	-	1.5	-	1.5
Total Phosphorous	(mg/l)	0.98	1.24	-	1.11
Standard Plate Count	(Organism/ml)	0	12	6	6
Total Coliform	(MPN/ml)	0	0	0	0
Fecal Streptococci	(MPN/ml)	2	0	0	1
Lead	(mg/l)	-	-	0.35	0.35
Mercury	(mg/l)	-	-	0.001	0.001

TABLE B-85. FLY ASH WEIGHTS

Collection Period	Fly Ash (kg)	Refuse (kg)	Weight % (wet)
12/09/76 - 12/10/76	350.7	399223	.09
12/17/76 - 12/18/76	307.0	453675	.07
01/03/77 - 01/04/77	595.4	559379	.11
03/07/77 - 03/11/77	1383.0	1610156	.09
Total	2636.1	3025069	.087

TABLE B-86. BOILER FLY ASH FUSION TEMPERATURES

		6/25/76*		7/30/77	
		Reducing	Oxidizing	Reducing	Oxidizing
Initial Deformation	°C	1049	1099	1088	1104
Softening Temperature	°C	1077	1132	1135	1127
Hemispherical Temperature	°C	1116	1160	1143	1138
Fluid Temperature	°C	1160	1232	1188	1182

* Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 6.

Feedwater Pump Work

During all tests monitored by SYSTECH the feedwater pump was driven by an electric motor. During some of the tests conducted by Monsanto the steam turbine driven pump was utilized. In Table B-7 the electric pump is shown to have an electric energy demand of approximately 104.9 kw. A portion of this electrical energy input enters the thermal cycle and appears as pump work on the feedwater. The pump work, shown as an input to the feedwater prior to entering the economizer/boiler, is calculated as follows. Since the water is highly incompressible, the equation $P = \dot{m}/vdp$ becomes $P = \dot{m}[v(p_2 - p_1)]$. To account for units, the equation takes the form of: $P = 0.102 \dot{m} v \Delta p$, where P is in joules/min. As an overall approximation, only an estimated 0.25 percent of the input power enters the thermal cycle as pump work. Similarly, in the case of the steam driven pump, the pump work entering the cycle is calculated in the same manner, and the percentage is the same. The remaining pump work is converted to heat and is rejected to the surroundings.

Delivered Steam

Steam delivered to the Baltimore Gas and Electric Company was measured using a totalizer meter located at the inlet to the utility steam main located approximately one mile from the plant. Readings were taken every hour, hence only averaged steam flow values over a one hour time period are available. Measurements used were obtained by taking the difference between two sequential readings.

Steam Line Losses

Steam line losses is a quantity which is very difficult to measure; it was determined based on an accounting of inputs and discharges. The resulting differential was ascribed to losses. The losses take the form of steam actually lost through leaks and steam lost by condensation in the delivery lines and vented to the sewers through water traps. Since no accounting can be made on a regular basis, the lost steam was calculated on a differential basis and reduced to a ratio based on line pressure and temperature. This approach accounts for losses considering that the total leakage area remains constant and that losses due to condensation are effected only by the steam temperature since the overall heat transfer coefficient remains constant. The mass flow of the steam loss was calculated by multiplying the boiler steam pressure by 1.5×10^{-4} .

Deaerating Heater Vented Steam Loss

To prevent a buildup of pressure, excess steam is vented through a nominal 3.81 cm pipe (1.5 in.) after the steam has bubbled to the water surface. The steam had been injected into the water from a pipe submerged in the water. The steam leaving the water is, naturally, not saturated at 222°F and 35 kPa (5 psig); but, during its progress through the vent pipe, it expands and is assumed to be saturated at 379°K and 25 kPa (3.6 psig). At the vent exit the steam is assumed to be superheated at 379°K and atmospheric pressure.

Assuming the pressure drop in the vent is due to friction pipe flow losses, the flow can be calculated to be 4.8 kg (10.6 lb) per minute.

Heat lost in the vented steam is calculated by multiplying the vent steam flow rate by the enthalpy of saturated steam at 379°K. This value of 12.9 MJ/min was used for all the tests since the temperature and pressure within the deaerating heater varies slightly.

Atomizing Steam Flow

No instrumentation was available to measure the atomizing steam flow to the fuel oil burners and, therefore, the steam flow was estimated based upon design values.

Each of the main kiln burners requires 6 kg (13.2 lb) of steam per minute at a burner head pressure of 725 kPa (105 psig). The gas purifier start-up burner requires 4.5 kg (10 lb) of steam per minute while the steam flow to the gas purifier pilot burner is 2 kg (4.5 lb) per minute. The atomizing steam flow is constant since the steam flow to all burners is maintained at all times during operation even when a burner is off.

The heat input of the atomizing steam was determined by multiplying the mass rate of the steam by its enthalpy.

Blowdown

While not determined regularly, feedwater and boiler solids concentrations (Table B-87) were measured to verify the design blowdown rate. The blowdown rates, calculated as a percentage of the feedwater rate, agreed well with the design 10 percent blowdown rate.

For purposes of determining the boiler blowdown heat loss, the blowdown was considered to consist of water only, and the enthalpy value assumed was that for saturated water at the boiler operating pressure.

THERMAL PROCESSING SUBSYSTEM BALANCES

The purpose of this section is to describe the approach used to determine representative mass and energy balances from all the data collected. In this section data from two sources are considered, that taken by Systems Technology Corporation and that taken during an earlier stage of the project by Monsanto EnviroChem Corporation. Two test points obtained by Systems Technology Corporation are analyzed in detail to obtain an understanding of the process mass and energy flows. The two tests are the standby test of 6/28/77 at 1530 and the refuse on-stream measured feed test of 7/1/77 at 0900.

The remaining data taken by Systems Technology is analyzed as a data set to verify assumptions generated with the two previously mentioned data points and to obtain statistical understanding of process variability. The Monsanto data are also treated as a data set and used to determine how well the assumptions made on earlier data sets fit this data, how well the data voids

TABLE B-87. BOILER WATER ANALYSIS

DATE		TOTAL SOLIDS (mg/l)	TOTAL DISSOLVED SOLIDS (mg/l)	CHLORIDES (mg/l)	pH	ALKALINITY (mg/l)	HARDNESS (mg/l)	IRON (mg/l)
2/1/77	Boiler Feedwater			20			0	
	Boiler Water	759		178	10.2	420	0	
	Constant Blowdown	772		158	10.6	400	0	
3/1/77	Boiler Feedwater	123					2	
	Boiler Water	1130		184		416		
	Constant Blowdown	1140		188		428		0.95
4/29/77	Boiler Feedwater	129			6.9		0	
	Boiler Water							
	Constant Blowdown	1140		182	10.8	350		6.45
5/10/77	Boiler Feedwater		102					
	Constant Blowdown		815					
5/12/77	Boiler Feedwater		105					
	Constant Blowdown		1130					
5/13/77	Boiler Feedwater		97					
	Constant Blowdown		1130					
5/14/77	Boiler Feedwater		91					
	Constant Blowdown		1080					

can be filled by these assumptions, and the extent to which the process varied from the operational character during Monsanto supervision of operations and subsequent operation by the City of Baltimore.

The standby and on-stream tests are presented as a series of independent measurements of various parameters, flow calculations, and analytical processes to verify assumptions made concerning the process. The standby and on-stream tests are used together as complimentary data points although the majority of the analysis is based on the standby test. The standby and on-stream summary section ties together the independent measurement sections indicating how these data points compliment each other.

Standby and Measured Refuse On-Stream Test Discussion

The lack of measured refuse flow test data makes the standby and single measured refuse flow tests of paramount importance in the process and thermal cycle analysis. The standby test because of the elimination of unknown process characteristics (waste heating value, mass flow, etc.) allows the calculation of otherwise unattainable heat transfer losses. The single measured refuse flow test point is important from the standpoint that it verifies the assumptions and generalized thermal calculations based on standby operation. The following narrative explains in general terms why measurements were made the way they were, why certain assumptions had to be made, and how the specific detailed measurement and calculation segments included in this section fit together.

The first objective was to define gas flows at the kiln crossover duct, gas purifier discharge, and boiler/economizer discharge using the methods discussed previously since air is the major flow material. It became apparent during initial calculation comparisons that both the kiln crossover duct and gas purifier discharge plans were not suitable measurement stations and alternative methods were required to determine the gas flows at those points. Fortunately, the boiler/economizer discharge duct provided an ideal measurement station. The measurement at this plane was, therefore, used as the standard of comparison for other flow measurements. It was determined that if the inputs were all measured or estimated accurately enough, the sum did in fact approximate the boiler discharge measurement. Substantial time was spent in correlating and determining procedures for evaluating combustion air flows and quench air flows. Discharged material, residue, slag, and spillback were estimated for the refuse on-stream case as well as the minor inputs such as atomization steam and quench pit water vaporization. The pressure of leakage air around the ram feeder plug was estimated to be the difference between the inputs and the measured boiler discharge duct flow. Both fuel flow and refuse flows were measured for the two tests under consideration. It must be admitted that a material balance of these two tests has an inherent inaccuracy since ram leakage flows were estimated from "forced" balances. A better evaluation of material flow estimates is seen in the remainder of the data obtained by SYSTECH where no leakage flow was assumed.

Heat flow for the standby test case although not simple, was completed assuming a balance could be accurately made and thus pinpoint otherwise incalculable heat flow rates. Heat flow into the kiln for the standby test consisted of sensible heat of the combustion air referenced to 273°K and the higher heating value of the No. 2 fuel oil multiplied by the quantity of oil was the major heat input to the kiln. Other heat inputs were atomization steam, quench pit water vapor, and ram leakage air. All were evaluated as shown in sections already discussed. The kiln heat loss was estimated by first calculating the heat transfer rate to determine the relative magnitude of the loss rate, and more precisely calculated by balancing the discharge heat flow at the crossover duct against the input heat flow. The difference was considered to be the kiln heat loss and was incorporated into a generalized heat loss equation based on the difference between kiln discharge temperature and the ambient air temperature.

Normally the heat loss from the gas purifier would be the next calculation, but since the temperature at the discharge of the gas purifier has been established to be in error, no meaningful estimate of gas purifier discharge heat can be obtained. Hence, it was necessary to start at the boiler discharge sampling station, and work upstream to determine this loss.

The boiler discharge heat is easily calculated from the gas constituent enthalpies and the gas component flow rates. Moving upstream, the boiler/economizer discharge duct heat loss was calculated and added to the discharge heat flow. The economizer surface heat loss rate was estimated to be 2.5 percent of the incoming heat flow based on experience with similar size and types of economizers. The heat flow from the boiler in the flue gas was calculated algebraically from the estimated economizer heat loss rate and the calculated economizer discharge heat rate, yielding a ratio of 1.0256 of the incoming heat to the discharge heat. The heat loss rate is then 0.0256 times the calculated economizer inlet heat flow. The boiler heat loss rate is estimated to be approximately 1 percent of the boiler inlet heat flow, but the heat transferred from the flue gas to the boiler water must first be calculated.

The preheater was balanced by calculating the heater skin losses and the vent steam lost. The cold feedwater heat was calculated based on flow rate and its inlet enthalpy. The two preheater losses are subtracted from the feedwater inlet heat content indicating normal progression of feedwater through the preheater. At the same time, steam is condensed into the feedwater raising its temperature inspite of losses caused by the elevated skin temperatures. The preheater steam essentially enters and leaves the preheater without loss, effectively making a loop of the boiler and preheater. After leaving the preheater, the hot water is pumped to boiler operating pressure, picking up the pump work sensible heat, which is added to the feedwater inlet heat content minus losses. In the boiler, heat transferred from the flue gas raises the water temperature creating steam. In the process, dissolved solids are precipitated and discharged in the blowdown liquid. The blowdown liquid represents a boiler heat loss. The remaining water is converted to steam and splits into three parts. The first part is preheater steam again, effectively making a cycle of the boiler and preheater

without loss. The second part of the steam is used for burner fuel atomization and was previously calculated. The remainder enters the export steam main for delivery to the Baltimore Gas and Electric Company. The steam flow meter at this point unfortunately is not an accurate measurement and, therefore, export steam must be calculated in two parts. Since the total feedwater is well known, the preheater vent loss is known and the blowdown liquid and atomization steam are known the remaining difference must be export steam, but this value does not agree with steam flow arriving at the B. G. & E. meter. The reason for the discrepancy is line losses. The line losses are calculated from a generalized equation developed from the known steam flow rate and the export steam calculated by differences from the feedwater.

At this point, all of the steam and water inputs and discharge rates for the boiler are calculated a summation results in the net heat transferred in the boiler. By summing the heat transferred and the heat discharged the inlet heat minus losses is known. Hence, the boiler inlet heat equals 1.0101 multiplied by the heat transferred and the heat discharged. The boiler loss heat is 1 percent of this value.

Moving to the next station upstream, there is a set of quench air ports which admit cooling air for the purpose of reducing gas temperatures to below the slag melting temperature. This air carries sensible heat calculated from the ambient temperature and mass flow rate. The difference between the quench air sensible heat and boiler inlet calculation heat flow rates is the gas purifier discharge heat flow. The difference between gas purifier inlet and discharge heat flows is the heat loss, and a generalized loss equation is developed. At the same time since the gas purifier discharge mean temperature is not evaluated by the facility thermocouple directly the mean temperature can be determined from the average gas enthalpy. A trial and error solution determines the gas purifier mean discharge temperature. A generalized equation can be developed from this information to correct the indicated facility measurements.

An assumption made in all of the foregoing discussions has been the knowledge of the steam quality produced. In fact, no steam quality measurements have been made at any time. The steam generated by the boiler, according to vendor specifications, is saturated at 99.5 percent quality steam at the rated heat load, but no measurements have been made to verify this. Also at heat loads below the rated value, the boilers produce steam of some again unknown quality. As a result, it was necessary to assume that the boiler is relatively typical of its type and performs so. It was further assumed that the design is conservative enough to assure steam at heat loads somewhat below rated. A level of 90 percent of rated was decided upon as the level at which saturated steam will be produced. This may be somewhat generous. It was further decided that the boiler as a typical boiler would not produce steam having less than 95 percent quality at normally encountered reduced heat loads. For lack of better data these two points were connected by a straight line to define a steam quality curve based on input heat loading. All results presented here use this curve to predict the steam quality.

In the final analysis, the information desired about the boiler and processing kiln is the efficiency. The mass and energy balances for the standby test are shown in Figures B-24 and B-25, respectively. During the standby test case the apparent efficiency of the thermal processing module was 69 percent. Of the heat reaching the boilers, 76 percent appeared as useable heat in the form of steam. By definition, the useable steam included delivered steam, steam lost in the export steam line, and atomization steam. The atomization steam would not be included as output steam when calculating the efficiency of the thermal processing subsystem since it remains internal to the system. The overall thermal processing subsystem efficiency was 51 percent, not accounting for electrical power consumed by the subsystem.

The best test of the validity of the estimates made using standby data is analysis of a measured refuse feed test. Figures B-26 and B-27 show the mass and energy balances for this test. Using the standby data to estimate the heat loss, the energy imbalance is -800 MJ/min (758,000 Btu/min) or 20 percent of the total input heat. The minus sign indicates that estimated energy outputs were higher than the inputs. This imbalance can be attributed to numerous factors: 1) the actual heat content of the refuse may have been higher than the laboratory analysis value, 2) the heat losses may have been overestimated, 3) the actual steam production was very likely lower than the measured value, and 4) the heat content and mass flow rate of the discharged residue could have been less than the assumed average values, due to complete combustion.

The calculated on-stream test efficiencies were; 54 percent for the thermal processing module, 98 percent for the heat recovery module (boiler) and 52 percent for the total thermal processing subsystem. The overall subsystem efficiency is a realistic value but the calculated boiler efficiency is well above 80 percent, the design level for the waste heat boilers. The efficiency calculated for the thermal processing module is extremely low, with the calculated outputs more than the inputs. The magnitudes of error introduced by the variables discussed above could reasonably account for this occurrence. The maximum variations from the average values used in the balances for the refuse heat content, residue mass rate, and the residue heat content were 40, 27 and 76 percent, respectively.

On-Stream Refuse Feed Tests Using Estimated Feed Rates

A total of eight additional full data sets were obtained by Systems Technology during the testing period 6/28/77 to 7/1/77. During these tests, no measured refuse flow data was obtained and all refuse flows were estimated based on the average shredding rate and the height of refuse piled on the conveyors. This naturally does not allow for packing factor or density of the refuse; resulting in inherent errors of unknown magnitude.

In all of the eight estimated refuse feed tests no ram leak air was assumed although it was present to some unknown degree in all cases. Refuse feed rate was estimated to be 530 kg/min. (35 tph) in all but the last case. In that case, the refuse feed rate was noticeably lower and was estimated to be 302 kg/min. (20 tph).

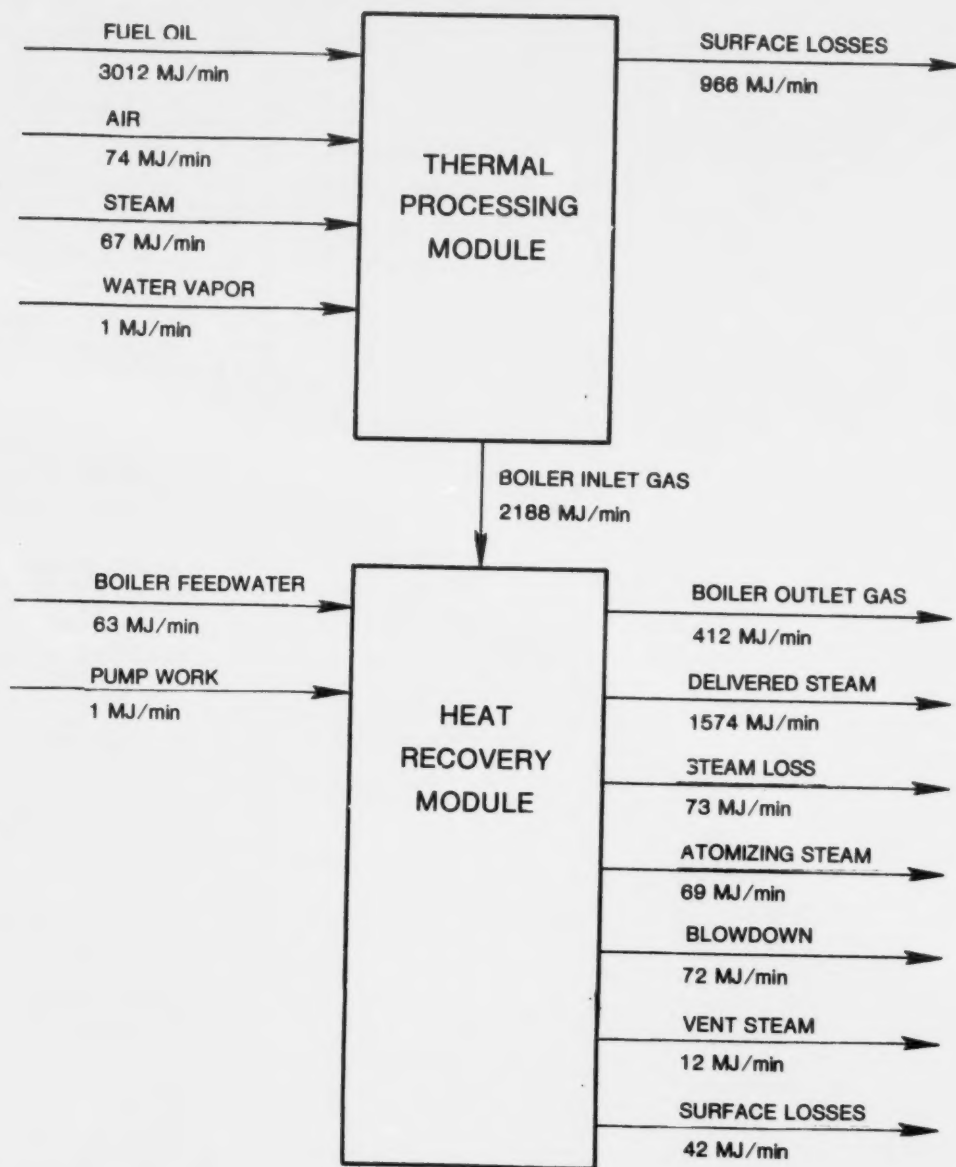


Figure B-25. Standby test energy balance.

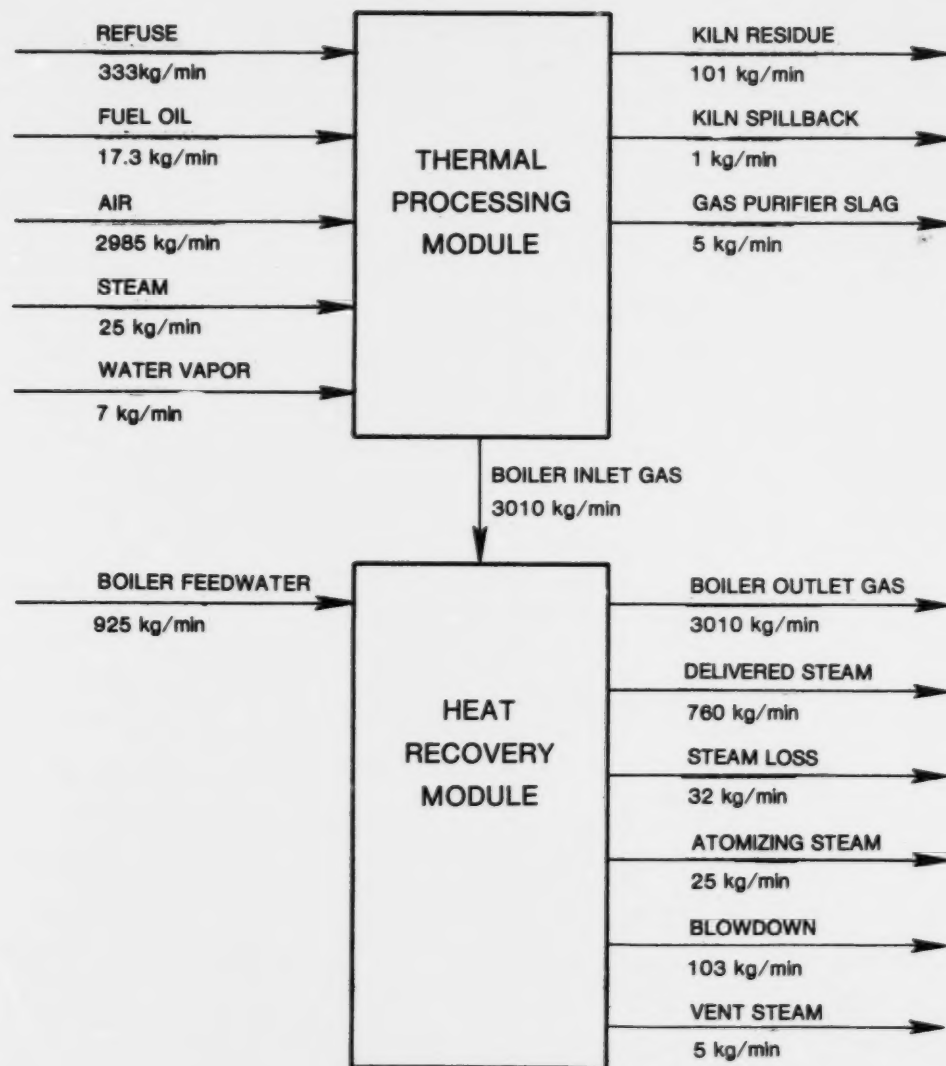


Figure B-26. On-steam test mass balance.

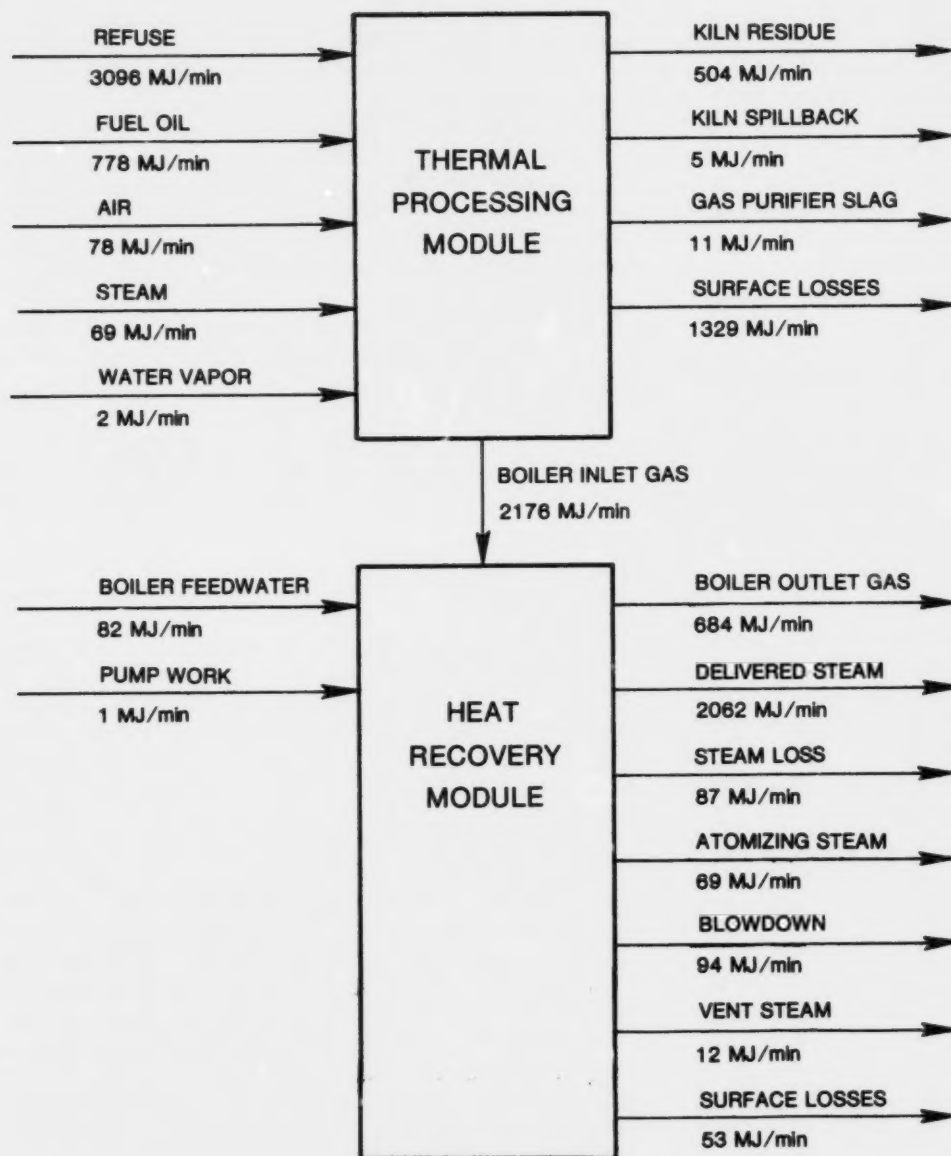


Figure B-27. On-steam test energy balance.

In each test, the mass and energy balances were determined in the manner already described. The absolute value of the difference between the summed inputs and the boiler/economizer discharge plane flow measurement for seven of the eight mass balances averaged 3.6 percent. The eighth case did not have boiler/economizer discharge plane data for use as a standard. The standard deviation of this data is 2.5 percent with four of the seven cases showing differences of less than 3 percent and no test having a difference greater than 8 percent.

Data of this caliber suggested that a statistical basis for correction of the kiln and gas purifier measurements might be possible. The deviation of summed inputs from measured values was determined using the summed inputs as a "true" value. For the kiln crossover duct gas flow measurement the average multiplication factor was 1.3526. This means that the gas flow values calculated from duct measurements should be multiplied by 1.3526 to obtain actual flow values. The standard deviation of error of the results will be 12.6 percent. For the gas purifier discharge measurement plane, the measurement values should be multiplied by 0.6898 to obtain actual values. The standard deviation of this calculation will be 7.1 percent.

The energy balances of the eight refuse processing data sets had an average difference of 7.9 percent with a standard deviation of 5.2 percent.

Four data sets exceeded the 10 percent limit normally considered to be an acceptable balance. All but one of the data sets indicated that calculated outputs were higher than the inputs due to one or a combination of the reasons discussed earlier.

Calculated efficiency of the thermal processing module ranges from 50 to 64 percent. The average efficiency was 61 percent with a standard deviation of 4.6 percent. The average calculated efficiency of the boilers was 79 percent with a 7.8 percent standard deviation. These data are biased because all but one data set shows more heat leaving the system than entering. Thermal processing subsystem efficiencies range from 42 percent to 55 percent. The average overall efficiency is 49 percent with a standard deviation of 4.8 percent.

Analysis of Process Data Taken by Monsanto EnviroChem

During the period from 11/3/76 to 1/24/77 Monsanto EnviroChem obtained a total of 44 sets of operational data from the Baltimore Landgard® plant. This included both standby and on-stream refuse feed tests. None of the data sets are complete in all respects though some are useable if reasonable assumptions concerning similarity of operation are made. In many cases, fuel oil flows had to be assumed. In numerous cases, steam flow had to be assumed the same as a similar test point several hours apart. Process airflow through the fans in most cases was well documented. In those cases where it was not, the curves of flow vs. damper position were used to estimate the air flow. Quench air was varied using both the slotted control ring and the butterfly valve. When the slotted control ring was closed, it was assumed that a minimal amount of leakage air still entered the port although this is

not an important percentage. No leakage air around the ram plug was assumed although it was probably present to some degree in all cases. Burner atomization steam and quench water were estimated in the same manner as during tests documented by Systems Technology. Boiler steam generation, and boiler and duct losses were estimated using the equations developed using the standby data obtained by Systems Technology. Kiln and gas purifier heat losses and temperatures were estimated in the same manner. Refuse feed rate for these tests is better documented than data obtained by Systems Technology.

During several of the tests, the feedwater pump was driven by a steam turbine. The steam for this purpose was not measured in any way, and had to be calculated by first determining the feedwater flow rate and the pressure rise. Using this information, the feedwater pump performance curve was entered to determine pump efficiency. Pump work output was then divided by the efficiency factor to obtain pump work input. Using the assumed input steam quality/enthalpy and the turbine exhaust steam enthalpy, the theoretical steam required was calculated by dividing required energy input by the steam enthalpy difference to obtain the required steam flow. This number was reevaluated by dividing by an assumed turbine efficiency of 90 percent to obtain a calculated steam usage. The turbine exhaust steam enthalpy was obtained by starting with the assumed turbine inlet steam enthalpy and expanding the steam isentropically to a pressure 69 kPa (10 psig) above the deaerating heater operating pressure. The deaerating heater is the exhaust receiver for the turbine discharge steam. Since this procedure does not result in an exact balance of steam with preheat steam around the preheater-boiler cycle the calculation is repeated with a new feedwater flow rate until the cycle balances. Note that the quantity of boiler feedwater pumped by the feedwater pump is effected by the pump's steam turbine discharge rate.

The energy balance for the ten useable Monsanto data sets (Table B-88) ranged from 0.01 percent unaccounted energy imbalance. The mean or the differences was 2.8 percent with a 2.3 percent standard deviation indicating that the data obtained is representative of actual conditions. The efficiency, of the thermal processing module averaged 66.8 percent with a standard deviation of 4.6 percent. This compares quite favorably with the process efficiency indicated by data obtained by Systems Technology. The conclusion which can be drawn from these results is that there is essentially no difference in process operation between the Monsanto and Systech data.

A different situation exists for the boiler data. During these tests a portion of the boiler inlet gases bypassed the boiler by flowing through the jug valve. Monsanto data indicates that boiler, on the average, only 62 percent of the energy discharged by the thermal processing module was converted to steam. Comparing this to the Systech data, indications are that sealing of the jug valve improved boiler steam production approximately 20 percent. This is a significant improvement and should justify the city's decision to eliminate that equipment item. As a result of the low boiler steam production the thermal processing subsystem efficiency is 41.2 percent with a standard deviation of 4.2 percent.

TABLE B-88. MONSANTO ENERGY BALANCE SUMMARY

Date Time	11/11/76 1240	11/11/76 1400	11/16/76 1530	12/7/76 1430	12/7/76 1500	12/13/76 0930	12/14/76 0900	12/16/76 0900	12/18/76 1300	12/24/77 1030
ENERGY FLOW (MJ/min)										
THERMAL PROCESSING MODULE										
KILN										
Inputs										
Air	7	8	7	6	8	1	2	5	4	-1
Refuse	4654	4575	5069	4507	4507	4930	4930	4930	3519	3519
Fuel Oil	156	156	5	231	231	80	231	5	48	50
Steam	18	18	18	18	18	18	18	18	18	18
Water	0	0	0	0	0	0	0	0	0	0
Outputs										
Off gas	4022	3951	4289	3954	3876	4196	4365	4077	2892	2767
Residue	208	204	222	203	223	221	217	235	144	168
Spillback	1	1	1	1	1	1	1	1	1	1
Surface loss	603	602	588	604	664	610	598	644	553	650
GAS PURIFIER										
Inputs										
Air	10	7	17	8	8	1	5	8	8	-2
Fuel Oil	20	80	80	80	80	80	80	80	80	80
Steam	18	18	18	18	18	18	18	18	18	18
Water Vapor	0	0	0	0	0	0	0	0	0	0
Outputs										
Off gas	3311	3251	3648	3538	3447	3493	3639	3369	2204	2102
Slag	16	15	16	10	10	16	16	16	11	11
Surface loss	804	803	742	513	525	785	812	798	781	750
QUENCH AIR										
Inputs										
Air	1	9	10	11	12	1	3	6	8	-1
Outputs										
Boiler inlet gases	3318	3260	3657	3538	3459	3494	3643	3375	2212	2101
ENERGY RECOVERY MODULE										
Inputs										
Water	24	26	17	17	18	20	21	21	8	9
Pump work	2	2	1	3	2	3	3	2	1	2
Outputs										
Delivered steam	1680	2058	2051	2145	2144	1940	1818	2210	1199	1359
Steam loss	72	76	74	80	85	87	76	71	99	66
Atomizing steam	35	35	36	35	35	12	36	35	35	35
Blowdown	80	87	56	97	96	113	114	110	45	70
Vent steam	12	12	12	12	12	12	12	12	12	12
Boiler loss	33	33	37	35	35	35	36	34	22	21
Economizer loss	30	25	32	27	26	26	29	30	22	13
Duct loss	17	16	14	14	13	14	13	14	12	8
Boiler outlet gas	1198	1001	1257	1079	1035	1042	1143	1181	884	523

Evaluation of Economizer Performance

Economizer effectiveness was evaluated in a rather simplistic manner with several assumptions. First, the economizer water inlet temperature differed significantly between the two economizers. The first having a temperature essentially the same as the deaerating heater discharge temperature. The second economizer water inlet temperature averaged 11 to 17°K (20 to 30°R) higher than the deaerating heater discharge temperature. This must be an instrument error because only heat loss can occur to the water in the connecting piping, and therefore, the lower of the two temperatures was used as an economizer inlet temperature for both economizers. The water flow split between the two economizer/boiler systems is not known and since the two economizer water discharge temperatures remained less than 3°K (5°R) apart for all data recorded the average of the two temperatures was used as the discharge temperature for both. Heat transferred to the water was calculated as the product of the water flow and temperature difference since for the pressure-temperature range of interest the specific heat averages for liquid water is approximately 1.0. The water flow used was the sum of the cold feedwater and preheat steam minus the preheater vent steam loss.

Heat recovered by the economizers ranged from a low of 17.6 percent for the standby case, to 26.9 percent for a total heat transferred by the two boiler/economizers combination. The mean percentage of heat transferred by the economizers appears to be approximately 20.5 percent. The data standard deviation is 2.4 percent.

Since the economizers are essentially extensions of the boilers, this quantity of heat would be lost without the economizers. In other words, without the economizers, approximately 20 percent of the heat presently recovered would be lost. This is particularly important since the economizers are going to be removed during the ongoing modifications.

SECTION B-5

RESIDUE SEPARATION AND SCRUBBER SYSTEM DATA

Because both of these systems are being removed or demolished, they will not be discussed further. However, for completeness, the data collected is presented in the following Tables and Figures.

TABLE B-89. MASS SPECTROPHOTOMETRIC ANALYSIS OF GAS SAMPLED AT THE SCRUBBER INLET*

DATE TIME	5/10/75 1145 %	5/30/75 1552 %	5/30/75 2105 %	5/31/75 1615 %	6/1/75 2100 %	6/12/75 1742 %	6/12/75 1740 %
Carbon Dioxide	2.11	10.59	11.14	10.03	4.81	4.86	11.84
Argon	0.74	0.78	0.79	0.78	0.75	0.75	0.79
Carbon Monoxide	0.80	2.39	2.42	2.31	1.24	1.56	2.58
Oxygen	19.39	9.66	9.16	9.75	16.27	16.47	8.13
Nitrogen	76.95	76.56	76.48	77.11	76.91	76.10	76.64
Methane	0.01	0.01	0.01	0.01	---	0.02	0.01
Hydrogen	---	---	---	---	---	0.24	---

DATE TIME	6/12/75 1735 %	6/16/75 1515 %	6/28/75 1730 %	7/2/75 2005 %	7/2/75 0855 %	7/2/75 0855 %	AVERAGE %
Carbon Dioxide	10.91	2.06	11.34	11.25	9.38	9.91	8.48
Argon	0.79	0.74	0.80	0.79	0.78	0.79	0.77
Carbon Monoxide	2.36	0.77	---	---	---	---	1.82
Oxygen	9.27	19.54	8.01	8.56	10.86	10.21	11.94
Nitrogen	76.66	76.86	79.80	79.39	78.97	79.04	77.50
Methane	0.01	0.02	---	---	---	---	0.01
Hydrogen	---	---	---	---	---	---	0.24

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 17.

TABLE B-90. SCRUBBER INLET PARTICULATE LOADINGS*

DATE	TIME	LOADING (g/DSCM)
5/30/75	1530	0.7968
5/30/75	2103	1.3280
5/31/75	1610	0.9937
6/01/75	2050	1.0647
6/13/75	1515	0.5770
7/25/75	1800	9.9785

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 15.

TABLE B-91. ANDERSON PARTICLE SIZE DISTRIBUTION OF SCRUBBER INLET GASES*

DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADING (g/DSCM)	WT. (%)	DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADING (g/DSCM)	WT. (%)
5/30/75	1530	7.80	0.105	12.53	6/01/75	2050	7.10	0.291	19.33
		5.10	0.023	2.72			4.70	0.096	6.39
		3.20	0.027	3.27			3.00	0.114	7.61
		2.30	0.039	4.63			2.10	0.096	6.39
		1.45	0.037	4.36			1.35	0.125	8.22
		0.75	0.080	9.54			0.69	0.160	10.65
		0.43	0.069	8.17			0.40	0.183	12.18
		0.30	0.085	10.08			0.27	0.197	13.09
		0.03	0.376	44.70			0.27	0.243	16.14
5/30/75	2103	7.60	0.089	6.38	6/13/75	1515	9.00	0.327	53.56
		4.90	0.039	2.78			5.70	0.057	9.36
		3.20	0.044	3.11			3.70	0.048	7.87
		2.20	0.071	5.07			2.60	0.041	6.74
		1.42	0.071	5.07			1.66	0.025	4.12
		0.72	0.087	6.22			0.85	0.007	1.12
		0.42	0.098	7.04			0.50	0.034	5.62
		0.29	0.165	11.78			0.34	0.039	6.37
		0.29	0.735	52.55			0.34	0.032	5.24
5/31/75	1610	6.80	4.692	10.06	7/25/75	1800	8.30	4.818	64.34
		4.50	0.041	3.70			5.30	0.918	12.26
		2.90	0.053	4.72			3.40	0.389	5.20
		2.00	0.055	4.93			2.40	0.174	2.32
		1.29	0.064	5.75			1.55	0.144	1.93
		0.66	0.092	0.21			0.79	0.165	2.20
		0.38	0.156	13.96			0.47	0.218	2.91
		0.26	0.069	16.43			0.32	0.153	2.05
		0.26	0.359	32.24			0.32	0.508	6.79

*Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 15.

TABLE B-92. ELECTRON PROBE MICRO ANALYSIS OF SCRUBBER INLET PARTICULATE*†

SIZE RANGE (MICRONS)	>7.80	5.10- 7.80	3.20- 5.10	2.30- 3.20	1.50- 2.30	0.80- 1.50	0.40- 0.80	0.30- 0.40	<0.30
PERCENT BY WEIGHT									
TOTAL	12.60	2.70	3.30	4.60	4.40	9.50	8.10	10.10	44.70
ALUMINUM	0.03	0.02	0.02	5.00	27.60	0.02	0.03	0.02	0.02
CALCIUM	3.60	4.60	6.20	7.20	9.00	4.60	2.40	3.00	6.00
COPPER	0.10	0.10	--	0.10	0.10	0.10	0.50	0.70	--
IRON	0.60	1.10	1.60	3.50	1.90	1.10	0.90	1.10	0.50
LEAD	0.10	0.20	0.10	0.20	0.10	2.00	2.40	4.30	0.10
MAGNESIUM	2.70	0.50	0.60	0.90	3.50	0.30	0.60	0.40	0.70
MANGANESE	0.02	0.60	0.12	0.19	0.10	0.06	0.04	0.04	--
SILICON	15.00	3.80	4.70	4.50	6.00	5.40	0.06	4.40	3.40
SODIUM	10.30	3.00	3.20	2.40	6.90	8.20	19.90	20.10	0.20
TIN	0.02	0.02	0.03	0.19	0.06	0.34	0.25	0.31	--
TITANIUM	0.17	0.02	0.04	0.51	0.25	0.03	0.02	0.02	--
ZINC	0.30	0.90	1.50	3.30	0.80	2.00	2.50	1.50	--

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 16.

† Collected 5/30/75 at 1530.

TABLE B-93. CAUSTIC CONSUMPTION

PERIOD	DAYS	TOTAL CONSUMPTION LITERS	CONSUMPTION PER DAY LITERS/DAY
11/6/76-11/8/76	3	16,230.1	5,408.8
11/11/76-11/14/76	4	46,037.0	11,510.2
11/16/76-11/17/76	2	17,028.7	8,516.3
11/25/76-11/28/76	4	40,446.5	10,109.7
12/6/76-12/7/76	2	10,643.4	5,321.7
12/17/76-12/18/76	2	20,223.3	10,113.5
12/20/76-12/21/76	2	18,762.2	9,379.2
1/2/77-1/23/77	12	69,621.3	5,802.4
TOTAL	31	238,992.5	7,706.3

TABLE B-94. TEMPERATURE OF SCRUBBER SYSTEM PROCESS WATERS

DATE	TIME	DEHUMIDIFIER COMPENSATE (°C)	SCRUBBER (°C)	DATE	TIME	DEHUMIDIFIER COMPENSATE (°C)	SCRUBBER (°C)
12/7/76	0140	39	52	1/14/77	1630	49	55
	0310	44	57	1/15/77	1600	47	53
12/8/76	2000	40	57		1720	46	52
12/10/76	1130	43	52	1/18/77	1115	43	49
	1715	44	54		1440	48	51
12/12/76	1230	47	56		1730	48	56
12/13/76	1015	43	52	1/19/77	1430	43	49
	1315	44	53	1/20/77	1245	43	50
	1635	44	54		1750	46	48
	1805	41	52	1/23/77	1030	41	41
12/14/76	0945	52	54	1/24/77	0915	51	52
	1230	43	52	1/31/77	0930	53	42
	1605	44	53		1455	49	51
12/15/76	0930	30	47	2/1/77	0730	47	44
	1745	45	48		1230	42	46
12/16/76	1015	43	54		1430	43	48
12/17/76	0940	45	39	2/3/77	2145	54	42
12/18/76	1145	49	54		2215	55	47
	1455	47	56	2/4/77	1115	52	50
	1650	44	52	2/5/77	1620	50	52
12/19/76	1015	36	51	2/6/77	1030	50	51
	1230	33	48	2/22/77	1200	40	
12/20/76	0940	36	48	2/25/77	0800	32	
	1345	32	48	2/28/77	1000	28	
12/21/76	0800	37	51	MINIMUM		28	39
	1015	36	51	MAXIMUM		55	57
	1200	38	52	AVERAGE		43	51

TABLE B-95. SOLIDS CONTENT OF SCRUBBER PROCESS WATERS

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
3/3/75*	2200	Suspended	1.56	3.07	108.60	1.43	9.56	6.96
		Dissolved	42.63	17.48	2.43	21.98	42.63	11.86
4/1/75*	0140	Suspended	5.37	4.69	22.69	1.50	5.37	5.91
		Dissolved	35.91	30.00	31.37	35.37	35.91	27.03
4/9/75*	2309	Suspended	111.40	29.60	879.00	88.00	111.40	4.23
		Dissolved	1050.40	610.20	8701.00	8849.00	1050.40	32.49
4/10/75*	0117	Suspended	50.40	17.80	181.00	59.00	50.40	2.34
		Dissolved	1043.40	877.50	1181.00	9125.00	1043.40	257.25
0309		Suspended	47.60	20.80	208.00	47.00	47.60	2.10
		Dissolved	962.00	593.90	8629.00	9403.00	962.00	26.24
0556		Suspended	83.30	12.00	517.00	62.00	83.30	1.50
		Dissolved	1503.40	690.60	348.00	10416.00	1503.40	24.28
1206		Suspended	62.10	14.90	321.00	44.00	62.10	1.46
		Dissolved	1166.00	793.20	11084.00	11946.00	1166.00	19.76
1304		Suspended	4.65	20.50	257.00	65.00	46.50	2.32
		Dissolved	1185.40	784.00	2136.00	11848.00	1185.40	32.99
1351		Suspended	84.70	15.30	2449.00	50.00	84.70	2.73
		Dissolved	1171.00	815.70	11126.00	11990.00	1171.00	33.34
1433		Suspended	70.00	21.00	90.00	63.00	70.00	2.45
		Dissolved	1198.60	809.20	1338.00	11690.00	1198.60	30.54
4/14/75*	2110	Suspended	180.00	60.00	600.00	60.00	180.00	10.00
		Dissolved	7651.00	4667.00	7654.00	7194.00	7650.00	227.00
4/15/75*	0000	Suspended	397.00		2139.00	50.00		194.00
		Dissolved	7817.00		7646.00	7481.00	246.00	1162.00
0210		Suspended	741.00	98.00	204.00	36.00		294.00
		Dissolved	8816.00	4488.00	7727.00	7703.00		2003.00
4/18/75*	1604	Suspended	730.00	132.00	8190.00	20.00	730.00	175.00
		Dissolved	6995.00	2285.00	2166.00	3506.00	2285.00	1498.00
1732		Suspended	1012.00	149.00	10198.00	30.00	1012.00	210.00
		Dissolved	6363.00	2927.00	2219.00	4246.00	6363.00	1509.00

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
4/18/75*	1900	Suspended	836.00	121.00	1346.00	23.00	836.00	136.00
		Dissolved	8442.00	3088.00	2215.00	4809.00	8442.00	1391.00
	2300	Suspended	869.00	70.00	11.00	30.00	869.00	50.00
4/22/75*		Dissolved	8215.00	3657.00	197.00	5531.00	8215.00	758.00
	0800	Suspended	1298.00	151.00	1710.00	44.00	1298.00	192.00
		Dissolved	13911.00	4228.00	2492.00	5966.00	13911.00	1878.00
	1010	Suspended	709.00	106.00	2.00	57.00	709.00	111.00
		Dissolved	11471.00	6404.00	140.00	9596.00	11471.00	1602.00
1205		Suspended	765.00	1118.00	132.00	92.00	765.00	126.00
		Dissolved	10903.00	6247.00	4106.00	13548.00	10903.00	1302.00
1410		Suspended	780.00	114.00	76.00	110.00	780.00	90.00
		Dissolved	8725.00	6344.00	411.00	9908.00	8725.00	962.00
2208		Suspended	574.00	180.00	76.00	52.00	574.00	214.00
		Dissolved	8576.00	8559.00	667.00	9252.00	8576.00	1386.00
4/27/75*	0220	Suspended	430.00	15.00	68.00	46.00	430.00	18.00
		Dissolved	8665.00	5644.00	553.00	8852.00	8665.00	270.00
0420		Suspended	888.00	176.00	99.00	165.00	888.00	99.00
		Dissolved	8495.00	4629.00	759.00	9151.00	8495.00	880.00
0615		Suspended	986.00	178.00	78.00	58.00	986.00	77.00
		Dissolved	8909.00	5708.00	2810.00	8848.00	8909.00	930.00
4/28/75*	0055	Suspended	660.00	210.00	40.00	20.00	660.00	50.00
		Dissolved	7870.00	6820.00	530.00	8090.00	7870.00	390.00
0255		Suspended	580.00	138.00	212.00	38.00	589.00	91.00
		Dissolved	5344.00	4531.00	2115.00	7303.00	5344.00	442.00
0435		Suspended	850.00	260.00	24.00	23.00	850.00	157.00
		Dissolved	6130.00	5810.00	2611.00	7088.00	6130.00	696.00
1300		Suspended	471.00	144.00	1673.00	20.00	907.00	78.00
		Dissolved	8104.00	6128.00	6685.00	7480.00	8264.00	768.00
1500		Suspended	907.00	187.00	2420.00	20.00	471.00	126.00
		Dissolved	8264.00	6121.00	6776.00	7151.00	8104.00	752.00

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
4/28/75*	1800	Suspended	2723.00	280.00	3972.00	22.00	2723.00	565.00
		Dissolved	9885.00	7114.00	6700.00	8387.00	9885.00	2420.00
	1942	Suspended	1805.00	275.00	155.00	14.00	1805.00	287.00
	2100	Dissolved	11774.00	7319.00	1124.00	9107.00	11774.00	1527.00
5/12/75*		Suspended	2192.00	372.00	660.00	15.00	2192.00	278.00
		Dissolved	12306.00	8150.00	1671.00	9824.00	12306.00	1921.00
	0130	Suspended	1186.00	53.00	1819.00	74.00	1186.00	22.00
	1330	Dissolved	8467.00	3649.00	9775.00	5910.00	8487.00	3919.00
5/19/75*		Suspended	1079.00	78.00	340.00	36.00	1079.00	152.00
		Dissolved	10217.00	6498.00	5659.00	10545.00	10217.00	898.00
	2000	Suspended	782.00	81.00	615.00	42.00	782.00	33.00
	1430	Dissolved	11075.00	6663.00	10292.00	10856.00	11075.00	885.00
5/30/75*		Suspended	1362.00	111.00	4746.00	67.00	1362.00	351.00
		Dissolved	7615.00	4041.00	3955.00	5336.00	7615.00	860.00
	1330	Suspended	409.00					78.00
	2140	Dissolved	7250.00					398.00
5/31/75*		Suspended	314.00					84.00
		Dissolved	8767.00					366.00
	1410	Suspended	514.00					120.00
	1530	Dissolved	9735.00					579.00
6/1/75*		Suspended	499.00					116.00
		Dissolved	10206.00					862.00
	2015	Suspended	462.00					227.00
	1620	Dissolved	12713.00					640.00
6/2/75*		Suspended	1010.00					390.00
		Dissolved	15780.00					1886.00
	1730	Suspended	116.00					92.00
		Dissolved	10476.00					816.00
6/16/75*	1000	Suspended	299.00					81.00
		Dissolved	11749.00					340.00

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
6/20/75*	0330	Suspended	339.00			54.00		24.00
		Dissolved	7183.00			5885.00		258.00
6/21/75*	0830	Suspended	526.00			108.00		60.00
		Dissolved	15510.00			15517.00		907.00
6/28/75*	1625	Suspended	849.00			128.00		45.00
		Dissolved	20846.00			19968.00		1055.00
7/17/75*	1730	Suspended	685.00			82.00		86.00
		Dissolved	6224.00			5537.00		457.00
7/18/75*	1200	Suspended	1366.00			47.00		69.00
		Dissolved	10288.00			9630.00		766.00
7/21/75*	1000	Suspended	1127.00			146.00		37.00
		Dissolved	11137.00			10979.00		812.00
	2000	Suspended	934.00			107.00		62.00
		Dissolved	14671.00			13466.00		734.00
7/23/75*	1100	Suspended	502.00			49.00		39.00
		Dissolved	125.00			2811.00		451.00
7/29/75*	1835	Suspended	694.00			50.00		25.00
		Dissolved	4727.00			3411.00		378.00
7/30/75*	1300	Suspended	1338.00			80.00		6774.00
		Dissolved	9145.00			8500.00		7452.00
9/14/75*	1730	Suspended	544.00					157.00
		Dissolved	26499.00					8862.00
9/17/75*	1415	Suspended	1761.00					
		Dissolved	29234.00					
	1700	Suspended	128.00					
		Dissolved						
6/9/76†	0000	Dissolved		10556.00	8419.00	53241.00		1117.00
		Suspended		292.00	303.00	28918.00		107.00
	2200	Dissolved	13899.00	12267.00	13459.00	87618.00		164.00
		Suspended	681.00	221.00	65.00	28941.00		32.00
						11847.00		
						96.00		
						11413.00		
						1769.00		

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
6/11/76 [†]	0515	Dissolved		14475.00		14754.00		821.00
		Suspended		246.00		41.00		88.00
6/22/76 [†]	0615	Dissolved	16894.00					
		Suspended	988.00					
6/25/76 [†]	1400	Dissolved		16519.00		16447.00		493.00
		Suspended		156.00		45.00		9.00
7/21/76 [†]	1300	Dissolved		4443.00		4751.00		987.00
		Suspended	6338.00			55.00		1190.00
	1830	Dissolved	7439.00	6222.00		7000.00		1076.00
		Suspended	295.00	95.00		61.00		78.00
7/22/76 [†]	1300	Dissolved	13880.00	11684.00	3981.00	12549.00		965.00
		Suspended	372.00	99.00	20971.00	60.00		42.00
	1600	Dissolved		17480.00				
		Suspended		136.00				
7/23/76 [†]	1600	Dissolved		17627.00	19154.00	18421.00		1386.00
		Suspended	20839.00	119.00	97.00	1858.00		134.00
7/29/76 [†]	1300	Dissolved	559.00		29938.00			
		Suspended	34888.00		81867.00			
8/5/76 [†]	1030	Dissolved	608.00					
		Suspended	23070.00	22362.00		24156.00		2361.00
8/6/76 [§]	1145	Dissolved	526.00	101.00		67.00		131.00
		Suspended	25568.00					1528.00
	1400	Dissolved	576.00					156.00
		Suspended	15980.00					1408.00
		Dissolved	468.00					188.00
11/05/76 [¶]		Suspended	40.00					
		Dissolved	2737.00					
11/08/76 [¶]		Suspended	86.00					
		Dissolved	11206.00					
11/12/76 [¶]	1030	Suspended	2023.00					
		Dissolved	21121.00					

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
11/13/76 [¶]	1230	Suspended	517.00					
		Dissolved	24793.00					
11/14/76 [¶]	1600	Suspended	820.00					
		Dissolved	28797.00					
11/15/76 [¶]	1200	Suspended	300.00					
		Dissolved	28453.00					
	1700	Suspended	703.00					
		Dissolved	31673.00					
11/16/76 [¶]	1030	Suspended	857.00					
		Dissolved	34637.00					
11/17/76 [¶]	1400	Suspended			273.00	140.00		
		Dissolved			31233.00	30937.00		
11/22/76 [¶]	0830	Suspended	143.00					
		Dissolved	660.00					
11/24/76 [¶]	0830	Suspended	47.00					
		Dissolved	1507.00					
11/26/76 [¶]	1030	Suspended	143			103.00		
		Dissolved	6877.00			6763.00		
11/23/76 [¶]	0800	Suspended	67.00					
		Dissolved	700.00					
11/27/76 [¶]	1030	Suspended	447.00					
		Dissolved	13323.00		5013.00	140.00		
11/29/76 [¶]	0800	Suspended	276.00		11707.00	12313.00		
		Dissolved	18533.00					
	1200	Suspended	580.00		50223.00	320.00		
		Dissolved	21593.00		20223.00	21080.00		
12/6/76 [¶]	1100	Suspended	144.00		144.00	140.00		
		Dissolved	11323.00		11913.00	11983.00		
12/7/76 [¶]	0800	Suspended	186.00					
		Dissolved	8137.00					

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
12/7/76 [¶]	1600	Suspended	457.00					
		Dissolved	6820.00					
12/7/76 ^{**}		Suspended						60.00
		Dissolved						1080.00
12/8/76 [¶]	0900	Suspended	273.00					
		Dissolved	10917.00					
12/10/76 [¶]	1130	Suspended	463.00		18823.00	220.00		
		Dissolved	14893.00		13857.00	15350.00		
12/12/76 [¶]	0830	Suspended	1030.00		18933.00	290.00		
		Dissolved	25576.00		21153.00	23740.0012		
12/14/76 [¶]	1000	Suspended	700.00		207.00	207.00		
		Dissolved	27940.00		30397.00	30397.00		
12/15/76 [¶]	0900	Suspended	1160.00					
		Dissolved	43243.00					
12/17/76 [¶]	0830	Suspended	617.00			490.00		
		Dissolved	31710.00			40693.00		
12/18/76 [¶]	1300	Suspended	783.00					
		Dissolved	49780.00					
12/20/76 [¶]	1000	Suspended	617.00			200.00		
		Dissolved	31577.00			33362.00		
12/21/76 [¶]	1300	Suspended	1063.00			273.00		
		Dissolved	44327.00			47807.00		
12/22/76 [¶]	1300	Suspended	600.00			270.00		
		Dissolved	51397.00			53017.00		
1/4/77 [¶]	0900	Suspended	603.00					
		Dissolved	5263.00					
1/7/77 [¶]	1600	Suspended	550.00					
		Dissolved	4163.00					
1/9/77 [¶]	1115	Suspended	337.00					
		Dissolved	11613.00					

(continued)

TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
1/10/77 [¶]	0830	Suspended	557.00					
		Dissolved	13250.00					
		Suspended	500.00					
1/11/77 [¶]	0900	Dissolved	13067.00					
		Suspended	513.00					
		Dissolved	15643.00					
		Suspended	487.00					
		Dissolved	14273.00					
	1100	Suspended	313.00					
		Dissolved	15323.00					
		Suspended	360.00					
		Dissolved	15987.00					
		Suspended	387.00					
1/11/77 [¶]	1400	Dissolved	17117.00					
		Suspended	583.00					
		Dissolved	18433.00					
1/13/77 [¶]	1230	Suspended	307.00					
		Dissolved	23620.00					
1/14/77 [¶]	0830	Suspended	627.00					
		Dissolved	21030.00					
1/18/77 [¶]	0845	Suspended	473.00					
		Dissolved	22087.00					
1/19/77 [¶]	1300	Suspended	823.00					
		Dissolved	23140.00					
1/20/77 [¶]	1245	Suspended	480.00					
		Dissolved	31917.00					
1/21/77 [¶]	0830	Suspended	500.00					
		Dissolved	4959.00					
		Suspended	587.00					
		Dissolved	5020.00					

(continued)

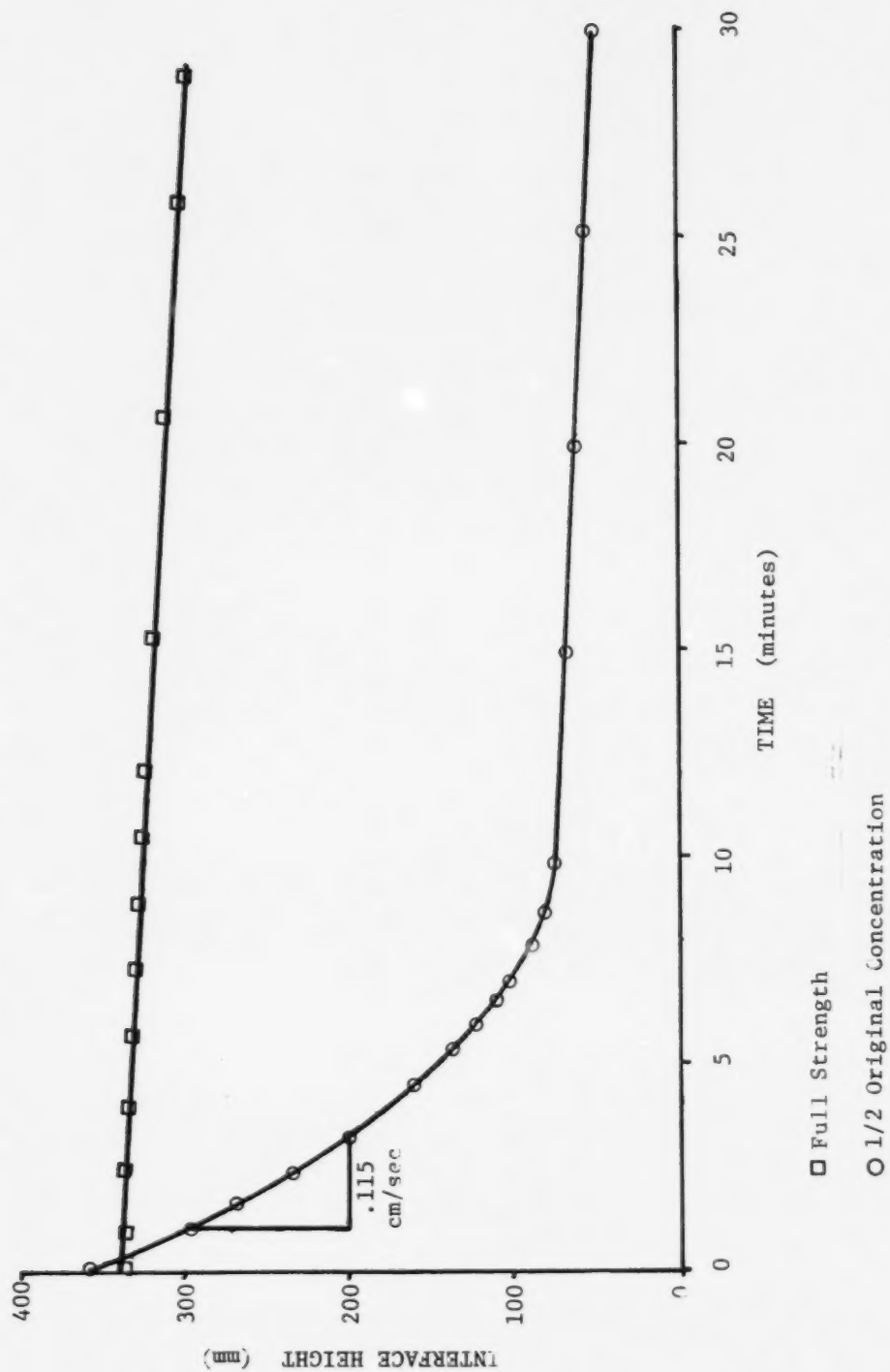
TABLE B-95. (Continued)

DATE	TIME	TEST	SCRUBBER (mg/l)	SCRUBBER SUMP (mg/l)	CLARIFIER UNDERFLOW (mg/l)	CLARIFIER OVERFLOW (mg/l)	CLARIFIER INFLUENT (mg/l)	DEHUMIDIFIER COMPENSATE (mg/l)
1/24/77 ^{††}	0850	Suspended	450.00					
		Dissolved	11160.00					190.00
1/31/77 ^{**}	1500	Suspended				22.00		4000.00
		Total				2610.00		9180.00
3/1/77 ^{**}		Suspended						75100.00
		Total						108.00
4/28/77 ^{**}	1630	Suspended						60600.00
		Total						

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 42.

†Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976. Table 13.

‡Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976. Table 14.



SOURCE: Unpublished Monsanto Data

Figure 28. Scrubber solids settling curves.

TABLE B-96. EMISSION SPECTROGRAPHIC ANALYSIS OF SCRUBBER
SYSTEM PROCESS WATERS AND THEIR FILTERABLE SOLIDS**

Location Time Type of Sample	Clarifier 1625		Overflow		Dehumidifier 1630		Scrubber		Discharge	
	Filterable Solids %	Filtered Process Waters %	Filterable Solids %	Filtered Process Waters %	Filterable Solids %	Filtered Process Waters %	Filterable Solids %	Filtered Process Waters %	Filterable Solids %	Filtered Process Waters %
Al	>1.0000	0.0010	>1.0000	0.0200	>1.0000	0.0200	>1.0000	0.0200	>1.0000	0.0200
B	0.0500	0.0700	0.0300	0.0600	0.0300	0.0600	0.0200	0.0400	0.0200	0.0400
Ca	>1.0000	0.1000	>1.0000	>0.1000	>1.0000	>0.1000	>1.0000	0.1000	>1.0000	0.1000
Cr	0.0800	0.0003	>0.1000	0.0001	>0.1000	0.0001	0.0600	>0.0001	0.0600	>0.0001
Cu	0.1000	0.0100	0.1000	0.0400	0.1000	0.0400	0.0800	0.0500	0.0800	0.0500
Fe	>1.0000	0.0010	>1.0000	0.0200	>1.0000	0.0200	>1.0000	0.0080	>1.0000	0.0080
K	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
Mg	>1.0000	0.0080	>1.0000	0.0100	>1.0000	0.0100	>1.0000	0.0100	>1.0000	0.0100
Mn	0.0800	ND	0.0070	0.0070	0.0070	0.0070	0.0800	ND	0.0800	ND
Mo	0.0080	0.0080	0.1000	0.0100	0.1000	0.0100	>0.1000	0.0080	>0.1000	0.0080
Na	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000	>1.0000
Ni	0.0200	ND	0.0400	ND	0.0400	ND	0.0200	0.0030	0.0200	0.0030
Pb	>1.0000	0.0300	>1.0000	0.0300	>1.0000	0.0300	>1.0000	0.0200	>1.0000	0.0200
Pt	Present	Present	Present	Present	Present	Present	Present	Present	Present	Present
Si	>1.0000	0.0700	>1.0000	>0.1000	>1.0000	>0.1000	>1.0000	0.100Sn	>1.0000	0.100Sn
Sn	>0.1000	ND	>0.1000	ND	>0.1000	ND	>0.1000	ND	>0.1000	ND
Sr	0.0100	0.0008	0.0100	0.0050	0.0100	0.0050	0.0100	0.0008	0.0100	0.0008
Ti	>0.1000	0.0030	>0.1000	0.0040	>0.1000	0.0040	>0.1000	0.0070	>0.1000	0.0070
V	0.0400	0.0010	0.0500	ND	0.0500	ND	0.0300	0.0010	0.0300	0.0010
Zn	>1.0000	ND	>1.0000	0.0700	>1.0000	0.0700	>1.0000	0.0300	>1.0000	0.0300
Zr	0.0050	ND	ND	0.0070	ND	0.0070	0.0100	ND	0.0100	ND

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 44.

TABLE B-97. ANALYSIS OF SCRUBBER PROCESS WATERS

Date Time	7/17/75* 1800 (mg/l)	2/29/76† 1300 (mg/l)	6/8/76§ 1145 (mg/l)	8/6/76§ 1400 (mg/l)	11/29/76 (mg/l)	12/7/76 (mg/l)	1/21/76 1500 (mg/l)	Average (mg/l)
Acidity							24	24
Alkalinity, CO ₃	415	196	198					270
Alkalinity, Total		3370	504	144	1980	90	40	1071
Ammonia	1.35							1.35
BOD ₅					8.5	3.0		5.8
Bromide	24							24
COD					106	61		83.5
Chloride	1351	25000	13500	8600	4580	3360	1030	8203
Fluoride	11.5							11.5
Hardness		48	204	209				154
Nitrate	17.5	13.70	13.53	7.13				12.97
Total Kjeldahl Nitrogen						1		1
Phosphate	2.5	0.44	1.78	1.95	42	50		1.67
Phosphorous, Total								46
Sulfate	2666	11560	7800	5000				6757

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 43.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 13.

§ Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 14.

TABLE B-98. pH OF SCRUBBER PROCESS WATER AND DEHUMIDIFIER CONDENSATE

DATE	TIME	DEHUMIDIFIER	SCRUBBER	DATE	TIME	DEHUMIDIFIER	SCRUBBER
11/2/76*	0000	2.4	7.8	11/6/76*	0000	5.5	7.1
	0200	6.0	7.0		0100	5.5	7.0
	2000	7.0	6.3		1200	5.5	7.0
	222	7.2	8.1		0300	5.6	7.0
11/3/76*	0000	7.2	8.3		0400	5.5	6.9
	0100	7.0	8.3		0500	5.4	6.9
	0200	7.0	8.2		0600	5.5	7.2
	0400	6.6	8.1		0700	5.8	7.0
	0800	6.3	7.8		0800	5.5	6.9
	1000	6.4	7.6		0900	5.3	6.6
	1300	6.2	7.6		1000	5.4	7.2
	1500	6.2	7.6		1100	5.3	7.3
	1700	6.0	7.5		1200	5.4	7.4
	1900	6.0	7.4		1300	5.4	7.8
	2000	5.8	7.7		1400	5.5	7.5
	2100	5.6	7.5		1700	5.5	6.2
	222	5.5	7.4		1800	3.4	6.6
11/4/76*	0100	6.7	7.7		1900	3.5	7.0
	0300	6.7	7.5	11/7/76*	2100	3.8	6.7
	0400	6.7	7.5		0000	3.4	7.0
	0700	4.7	6.7		0100	3.5	6.8
	0900	5.3	7.0		0200	3.5	7.1
	1100	5.6	7.8		0300	5.2	7.2
	1400	5.4	7.2		0500	5.4	7.1
	1500	5.5	7.3		0900	5.6	8.2
	1700	5.4	7.5		1000	5.2	6.9
	1900	6.2	7.4		1200	5.6	7.0
	2100	6.5	7.2		1600	5.8	6.9
11/5/76*	0000	6.5	7.5		1700	5.6	7.3
	0100	7.0	7.2		1800	5.6	7.1
	0200	7.0	7.2		2000	5.8	6.9
	0300	6.5	7.2		2200	5.7	6.8
	0400	7.0	7.1	11/8/76*	0000	3.3	6.9
	0500	5.5	7.1		0100	4.7	6.6
	0600	5.4	7.0		0200	4.5	6.5
	0700	6.5	7.0		0300	5.0	7.1
	0800	6.1	7.2		0400	4.5	6.9
	1100	5.0	6.0		0500	3.5	6.8
	1200	5.5	7.3		0600	3.6	6.6
	1400	5.5			0800	3.5	7.0
	1500	6.0	7.6		1000	5.0	7.2
	1700	5.5	7.2		1100	4.5	7.2
	1900	5.5	7.4		1700	3.8	7.0
	2100	5.6	6.8	11/9/76*	0000	3.5	7.0
	2200	5.5	7.1		0100	3.2	7.0

TABLE B-98. (Continued)

DATE	TIME	DEHUMIDIFIER	SCRUBBER	DATE	TIME	DEHUMIDIFIER	SCRUBBER
11/9/76*	0200	3.3	6.8	11/17/76*	1200	5.6	7.6
	0300	4.0	6.9		1500	4.5	7.4
11/10/76*	1600	6.5	8.2		1700	4.4	7.3
	2200	6.4	8.1		2100	4.5	7.5
11/11/76*	0600	6.0	8.0	11/24/76*	0100	5.1	6.9
	0700	5.7	7.8		0300	5.2	7.1
	0900	5.6	7.8		0600	5.5	7.0
	1000	5.7	7.7		1000	5.2	7.0
	2200	3.3	6.6		1400	5.0	6.8
11/12/76*	0100	3.3	6.2	11/25/76*	0100	5.3	6.9
	0300	3.5	6.3		0600	5.3	7.4
	0600	3.5	6.3		1000	5.0	7.0
	0900	3.0	6.5		1100	5.2	7.1
	1100	3.5	6.2		1400	5.3	7.9
	1300	3.6	6.4		1700	2.5	7.1
	1400	3.7	6.8		2100	3.2	6.8
	1700	3.6	7.7	11/26/76*	0700	3.5	6.9
11/13/76*	0200	3.5	6.9		0800	3.6	6.1
	0500	3.2	6.5		0900	3.6	6.9
	0600	3.2	6.5		1000	3.5	6.9
?	0800	3.3	6.4		1100	3.5	7.4
	2100	4.0	6.8		1200	3.3	7.1
11/14/76*	0200	3.4	6.8		1300	3.3	7.0
	1500	3.4	6.7		1400	2.9	7.0
	0900	3.4	6.6		1500	3.5	7.3
	1200	3.3	6.3		1600	5.0	7.0
	1400	3.5	7.0		1700	4.6	7.2
	1700	4.5	6.8		1900	5.1	8.4
	2100	4.0	6.9		2200	3.9	6.8
11/15/76*	0500	5.4	6.5	11/27/76*	0300	3.5	7.9
	0800	5.0	6.3		0600	2.9	6.8
	1100	5.5	6.8		0900	3.5	7.5
	1500	3.5	6.7		1000	3.5	7.2
	1700	3.0	6.6		1200	3.4	6.2
	2100	4.5	6.8		1300	4.0	7.5
11/16/76*	0000	3.8	6.8		1400	4.2	7.2
	0300	3.5	6.6		1500	4.0	7.4
	0800	4.6	8.0		1700	2.9	6.2
	0900	4.4	7.3		1800	3.3	6.8
	1400	3.8	7.3		1900	3.0	7.7
	1700	4.5	7.0		2000	3.1	7.2
	1900	3.8	6.8		2100	3.3	7.7
	2200	4.4	7.0		2200	3.4	7.7
11/17/76*	0200	3.7	6.6	11/28/76*	0000	3.5	7.5

TABLE B-98. (Continued)

Date	Time	Dehumidifier	Scrubber	Date	Time	Dehumidifier	Scrubber
11/28/76*	0500	4.8	7.5	12/18/76	1145	3.9	8.9
	0700	5.6	7.6		1455	3.7	7.5
	1000	6.1	7.4		1650	3.3	7.3
	1300	5.7	6.3	12/19/76	1015	4.4	8.7
	1500	3.4	5.4		1230	4.4	8.5
	1700	4.4	8.0	12/20/76	0940	4.0	8.7
	1800	4.9	7.7		1345	4.2	8.4
	1900	4.5	7.3	12/21/76	0800	3.2	6.7
	2100	5.1	7.5		1015	3.2	5.9
11/28/76		7.2	8.7		1200	3.3	7.0
12/05/76*	0200	6.1	7.2	01/13/77	1630	4.6	8.2
	0300	6.0	7.1	01/14/77	1020	2.9	6.2
	0400	6.0	7.0	01/15/77	1600	2.8	6.6
12/06/76*	0100	6.0	7.8		1720	2.7	9.3
	0700	6.4	7.0	01/18/77	1115	3.2	
	0900	6.0	6.3		1440	2.9	8.2
	1800	5.8	7.0		1730	3.0	10.3
12/07/76	0140	4.0	7.3	01/19/77	1430	2.9	9.0
	0310	3.5	5.9	01/20/77	1245	3.0	6.2
12/09/76	2000	3.7	6.5		1750	3.0	8.2
12/10/76	1130	4.1	7.0	01/23/77	1030	2.9	6.5
	1715	3.7	6.8	01/24/77	0915	2.8	7.6
12/12/76	1230	3.2	4.4	01/31/77	0930	2.5	6.6
12/13/76	1015	3.9	7.2		1455	2.7	6.0
	1315	3.8	6.6	02/01/77	0730	3.2	6.8
	1635	3.7	7.0		1230	3.1	6.4
	1805	3.8	6.0		1430	3.2	8.4
12/14/76	0945	4.3	7.7	02/03/77	2145	3.4	6.6
	1230	4.7	8.7		2215	3.2	7.8
	1605	4.5	8.6	02/04/77	1115	2.6	7.3
12/15/76	0930	5.4	7.9	02/05/77	1620	4.7	8.8
	1745	3.0	7.3	02/06/77	1030	6.5	10.2
12/16/76	1015	3.4	7.0	02/22/77	1200	2.8	
12/17/76	0940	3.2	7.1	02/25/77	0800	2.4	

* City of Baltimore Daily Log

TABLE B-99. pH OF SCRUBBER SYSTEM PROCESS WATERS

DATE TIME	3/3/75* 2200	4/1/75* 0140	4/9/75* 2309	4/10/75* 0117	4/10/75* 0309	4/10/75* 0556
P5/P6	9.90	4.94	8.72	8.44	7.59	9.18
P18	7.58	6.49	10.06	9.78	9.86	9.69
Clarifier Overflow	7.96	8.16	10.06	9.88	9.85	9.81
Clarifier Underflow	9.12	8.21				
Dehumidifier	4.80	3.23	8.12	7.30	6.73	7.50
Clarifier Return	9.90	4.94	8.72	8.44	7.59	9.18
DATE TIME	6/9/76† 0000	6/9/76† 2200	6/11/76† 0515	6/22/76† 0615	6/25/76† 1400	7/21/76† 1300
P5/P6		6.15		8.90		9.65
P18	9.85	12.04	12.23		12.30	7.73
Clarifier Overflow	7.47	7.50	8.29		8.01	7.76
Clarifier Underflow	8.85	7.50				
Dehumidifier	3.22	3.32	3.50		3.66	3.15
Hydroclone In	5.71		8.36			
Hydroclone Out	6.49			9.05		9.28
Hydroclone Desand	9.10			7.50		
DATE TIME	7/21/76† 1830	7/22/76† 1300	7/22/76† 1600	7/23/76† 1600	7/29/76† 1300	8/5/76† 1030
P5/P6	7.90	9.00		8.65	8.25	8.70
P18	8.43	8.35	7.40	8.12		8.80
Clarifier Overflow	8.65	8.84		8.30		8.60
Clarifier Underflow		8.60	8.32		8.30	
Dehumidifier	3.12	3.05	3.04	3.00		6.74
C8 Drain		4.05				
V9 Underflow		7.06		6.89	7.60	8.35

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 42.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 13.

TABLE B-100. CORROSION RATES BASED ON ULTRASONIC MEASUREMENT*

LOCATION	METAL THICKNESS (mm)	ESTIMATED CORROSION RATE (mm PER YEAR)
Clarifier	4.445-5.460	0 -0.125
Clarifier Overflow to P18 Sump	6.860-7.240	0
P18 Discharge to Scrubber	7.365-8.635	0
P5/P6 Discharge	7.110-7.240	0.125
12" Line to Scrub Tower Loops	9.020-10.030	0 -0.125
1st Scrub Tier Loop	6.860-7.620	0 -0.125
1-1/2" Lance First Level	3.555-3.940	1.000
Duct Scrub Tower To C8 Fan	6.100-6.350	0.500
Duct, C8 Fan To Dehumidifier:		
S Curve	5.205-6.100	0.500
At EPA Sample Point	6.100-6.600	0.125-0.250
Part Leg of C8 Fan	5.840-6.100	0.500
C8 Fan Housing	9.270-9.400	0.125-0.250
Boiler Discharge Duct at Economizer	5.205-6.100	0.500

* Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 15.

TABLE B-101. EVALUATION OF ALLOYS FOR INCINERATOR SCRUBBERS*

Alloy	Corrosion Results	
	Scrubber Solutions	Fan Deposits
Ti6Al-4V	Good resistance	Good resistance
Hastelloy C	Good	Good
Inconel 625	Good	Good
Hastelloy F	Good	--
Hastelloy C-276	Good	--
Hastelloy G	Good	--
Ti75A	Good	Pitted
S-816	Good	Pitted, SCC
Carpenter 20	Pitted	Pitted
Incoloy 825	Pitted	Pitted
Incoloy 800	--	Pitted, SCC
316L	Pitted, SCC	--
310	Pitted	--
446	Pitted	--
Inconel 600	Trenches	--
Inconel 601	Trenches	--
Armco 22-13-5	Pitted	Pitted, SCC
USS 18-18-2	Pitted	Pitted, SCC
Type 304	Pitted, SCC	Pitted, SCC

* Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 16.

TABLE B-102. FLOCCULANT EFFICIENCIES*

	SETTLING TIME (hours)	HERCULES FLOCCULANT 818.2 812.3 (mg/l)	SUSPENDED SOLIDS BEFORE SETTLING (mg/l)	SUSPENDED SOLIDS AFTER SETTLING (mg/l)	EFFICIENCY (%)
Actual Clarifier	7	0	3664	41	98.9
Actual Clarifier	4.5	0	2809	30	98.9
Clarifier Influent	3.0	0	3664	111	97.0
Clarifier Influent	3.0	0	2809	321	88.6
Actual Clarifier	7	2.5	3664	53	98.6
Actual Clarifier	4.5	5.0	2809	50	98.2
ESP Drain #1	3.0	0	377	52	86.2
ESP Drain #2	3.0	0	719	94	86.9
ESP Drain #1	3.0	2.5	377	44	88.3
ESP Drain #2	3.0	5.0	719	59	91.8
20% ESP-80% Scrubber	3.0	0	1381	79	94.3
20% ESP-80% Scrubber	3.0	2.5	1381	33	97.6

* Monsanto Unpublished Data.

TABLE B-103. CLARIFIER EFFICIENCY*

Date	Time	Influent Suspended Solids (mg/l)	Effluent Suspended Solids (mg/l)	Removal Efficiency (%)
11/17/76	1400	300	140	53
11/26/76	1030	140	100	29
11/27/76	1030	450	140	69
11/29/76	1200	580	320	45
12/06/76	1100	140	140	0
12/10/76	1600	460	220	52
12/13/76	0830	1030	290	72
12/14/76	1000	700	210	70
12/17/76	0830	617	490	21
12/20/76	1000	617	200	68
12/21/76	1300	1063	273	74
12/22/76	1300	600	270	55

* Unpublished Monsanto Data.

TABLE B-104. SPARK SOURCE MASS SPECTROMETRIC ANALYSIS
OF SCRUBBER INLET AND EXIT PARTICULATE

CONCENTRATION ($\mu\text{g}/\text{m}^3$)					
ELEMENT	INLET	OUTLET	ELEMENT	INLET	OUTLET
H	†	†	Rh	§	§
Li	131	1.69	Pd	§	§
Be	0.05	0.02	Ag	15.0	8.47
B	§	§	Cd	49.6	13.2
C	†	†	In	¶	¶
N	†	†	Sn	>1663	337
O	†	†	Sb	466	119
F	§	§	Te	.50	§
Na	§	§	I	.33	§
Mg	§	§	Cs	§	5.08
Al	§	§	Ba	>1663	152
Si	§	§	La	13.8	3.9
P	>1663	>1694	Ce	15.6	4.07
S	> 882	>1152	Pr	1.3	0.33
Cl	§	§	Nd	2.8	1.19
K	§	§	Sm	1.0	0.68
Ca	§	§	Eu	0.17	0.17
Sc	0.67	0.17	Gd	0.67	0.51
Ti	>1663	16.9	Tb	0.17	0.17
V	1.67	§	Dy	0.67	§
Cr	>1663	35.6	Ho	0.67	§
Mn	1512	15.3	Er	0.33	§
Fe	>1663	813	Tm	0.10	§
Co	282	2.03	Yb	0.83	§
Ni	472.5	40.7	Lu	0.15	§
Cu	15.1	168	Hf	0.83	§
Zn	>1663	>1694	Ta	0.83	§
Ga	15	13.6	W	1.50	§
Ge	3.3	10.2	Re	§	§
As	26.6	27.1	Os	§	§
Se	8.3	1.69	Ir	§	§
Br	6.7	§	Pt	§	§
Rb	4.5	23.4	Au	§	§
Sr	9.3	27.1	Hg	2.58	3.31
Y	0.67	0.68	Tl	§	§
Zr	§	6.78	Pb	>1663	>1694
Nb	.17	§	Bi	5.0	6.78
Mo	32.4	9.3	Th	1.66	3.39
Ru	§	§	U	§	§

* TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. pp. 25-27.

† Not detectable.

§ Approximately equal to blank.

¶ Standard.

TABLE B-105. NITROUS OXIDE EMISSION DATA

Date	Time	Boiler Exit (mg/m ³)	Scrubber Outlet (mg/m ³)
06/12/75*	1712		298
06/12/75*	1716		240
06/12/75*	1803		199
06/16/75*	0945		394
06/16/75*	0945		356
06/16/75*	0945		356
06/16/75*	0945		324
06/16/75*	1000		320
11/15/76†	1550	36	21
11/15/76†	1618	25	0.7
11/16/76†	1145	16	15
11/16/76†	1218	0.9	3
11/16/76†	1237	1	5
11/16/76†	1252	0.9	16
11/16/76†	1453	0.5	5
11/16/76†	1533	10	11
11/16/76†	1617	5	4

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 25.

† TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. pp. A-32-A35.

TABLE B-106. SCRUBBER OUTLET ORSATS

DATE	TIME	CO ₂ %	O ₂ %	CO%	DATE	TIME	CO ₂ %	O ₂ %	CO%
3/24/75*	2255-2348	5.40	13.60	0	7/18/75*	1142-1136	14.06	7.10	0
3/25/75*	1045-1148	5.40	13.60	0	7/23/75*	1017-1217	12.60	6.00	0
4/ 9/75*	0145-0249	8.60	10.10	0.01	7/23/75*	0956-1212	15.90	6.00	0
	0387-0523				7/30/75*	1331-1729	12.60	6.20	0
4/10/75*	1205-1342	7.00	14.00	0	6/ 9/76†	1713	12	6	-
4/18/75*	1730-2018	8.50	11.80	0	7/23/76†	1048	11.0	3.5	-
4/27/75*	0411-0548	10.50	8.50	0	8/ 5/76†	0800	11.0	8.0	-
4/28/75*	0115-0330	13.50	8.30	0	8/ 5/76†	1145	11.0	8.0	-
4/28/75*	1242-1407	12.40	7.00	0	8/ 7/76†	1530	11.0	8.0	-
4/28/75*	1755-1950	12.60	4.10	0	8/ 7/76†	1542	11.0	8.0	-
6/12/75*	1300-1320	10.60	10.10	0	11/15/76§	1540-1700	9.5	-	-
6/12/75*	1513-1609	10.60	10.10	0	11/16/76§	1120-1240	9.5	-	-
7/17/75*	1716-1916	15.45	5.00	0	11/16/76§	1440-1555	8.0	-	-
		Minimum			5.40			3.5	0
		Average			10.79			8.32	0.00
		Maximum			15.90			14.00	0.01

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 22.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 7.

§ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. Table 2, p. 21.

TABLE B-107. MASS SPECTROPHOTOMETRIC ANALYSIS OF SCRUBBER OUTLET GAS*

DATE TIME	6/17/75 1910	6/20/75 8030	6/27/75 2025	6/28/75 1710	7/2/75 1820	7/2/75 1820	7/17/75 -----	7/12/75 1845
	Volume %							
Carbon Dioxide	5.40	7.61	10.69	9.95	14.40	14.26	17.44	15.68
Argon	0.75	0.78	0.78	---	0.80	0.79	0.79	0.79
Carbon Monoxide	1.42	0.22	---	---	---	---	---	---
Oxygen	15.96	12.18	9.34	10.79	4.76	4.41	1.57	3.57
Nitrogen	76.44	79.20	79.16	79.25	80.01	80.49	80.20	79.96
Methane	0.02	0.01	---	---	---	---	---	---
Hydrogen	---	---	---	---	---	0.02	---	---

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 31.

TABLE B-108. ANALYSIS OF BOILER AND SCRUBBER OUTLET CASES

Date	Time	Test	Boiler Outlet (mg/SCM)	Scrubber Outlet (mg/SCM)
07/02/75*	0719	Cl ⁻		35.0
07/02/75*	0725	Cl ⁻		16.0
07/02/75*	1005	Cl ⁻		45.0
07/02/75*	1006	Cl ⁻		59.0
06/23/76†	1402	Cl ⁻		0.8
06/23/76†	1455	Cl ⁻		3.6
06/25/76†	0833	Cl ⁻	100.1	
06/25/76†	1507	Cl ⁻	261.4	
11/15/76§	1548-1618	Cl ⁻	560.0	
11/15/76¶	1614-1644	Cl ⁻		97.0
11/16/76§	1118-1148	Cl ⁻	1079.0	
11/16/76¶	1232-1302	Cl ⁻		196.0
11/16/76§	1459-1529	Cl ⁻	1567.0	
11/16/76¶	1605-1635	Cl ⁻		215.0
11/15/76§	1548-1618	F ⁻	10.0	
11/15/76¶	1614-1644	F ⁻		0.9
11/16/76§	1118-1148	F ⁻	9.0	
11/16/76¶	1232-1302	F ⁻		1.2
11/16/76§	1459-1529	F ⁻	4.0	
11/16/76¶	1605-1635	F ⁻		1.8
11/15/76§	1548-1618	Acidity	80.0	
11/15/76¶	1614-1644	Acidity		Basic
11/16/76§	1118-1148	Acidity	536.0	
11/16/76¶	1232-1302	Acidity		Basic
11/16/76§	1459-1529	Acidity	Basic	
11/16/76¶	1605-1635	Acidity		Basic
07/02/75*	0725	SO _x		0.9
06/23/76†	1340	SO ₂		158.6
06/23/76†	1433	SO ₂		302.7
06/25/76†	0800	SO ₂	525.4	
06/25/76†	1450	SO ₂	307.5	
07/27/76**	2000	SO ₂		8.2
08/05/76**	1845	SO ₂	320.3	
08/05/76**	2222	SO ₂		32.1
08/06/76**	1816	SO ₂		15.5
11/15/76††	1535-1635	SO ₂	453.8	
11/15/76§§	1537-1637	SO ₂		21.3
11/16/76††	1113-1213	SO ₂	415.7	
11/16/76§§	1115-1215	SO ₂		40.5
11/16/76††	1450-1550	SO ₂	319.1	
11/16/76§§	1452-1552	SO ₂		19.7

(continued)

TABLE B-108. (Continued)

Date	Time	Test	Boiler Outlet (mg/SCM)	Scrubber Outlet (mg/SCM)
07/23/76†	1340	SO ₂		14.6
06/23/76†	1433	SO ₂		19.5
07/27/76**	2000	SO ₂		36.8
08/05/76**	1854	SO ₂	47.9	
08/05/76**	2222	SO ₂		37.6
08/06/76**	1816	SO ₂		7.37
11/15/76††	1535-1635	SO ₂	35.9	
11/15/76§§	1537-1637	SO ₂		31.0
11/16/76††	1113-1213	SO ₂	37.4	
11/16/76§§	1115-1215	SO ₂		28.1
11/16/76††	1450-1550	SO ₂	23.3	
11/16/76§§	1452-1552	SO ₂		22.3
07/02/75*	0719	NH ₃		0.4
07/02/75*	0725	NH ₃		0.1
07/02/75*	1005	NH ₃		0.2
07/02/75*	1006	NH ₃		0.5

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 24.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 11.

§ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. Table 4, p. 23.

¶ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. Table 3, p. 22.

** Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 12.

†† TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. p. A-30.

§§ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 69-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. p. A-31.

TABLE B-109. MOISTURE CONTENT OF SCRUBBER OUTLET GASES

DATE	TIME	% MOISTURE	DATE	TIME	% MOISTURE
2/21/75*	1920-2020	45.98	7/17/75*	1716-1916	60.00
3/06/75*	1348-1448	44.82	7/18/75*	1142-1136	56.44
3/06/75*	1720-1820	50.40	7/23/75*	1017-1217	54.34
3/13/75*	1415-1515	49.96	7/24/75*	0956-1212	48.24
3/13/75*	1745-1845	51.21	7/30/75*	1331-1729	60.41
3/24/75*	2255-2348	45.23	6/ 9/76†	1713	53.5
3/25/75*	1045-1148	43.64	7/23/76†	1048	34.8
4/09/75*	0145-0249		8/05/76†	0800	36.8
	0387-0523	50.98	8/05/76†	1145	32.3
4/10/75*	1205-1342	49.12	8/07/76†	1530	32.4
4/18/75*	1730-2018	54.40	8/07/76†	1542	27.9
4/27/75*	0411-0548	46.70	11/15/76§	1540-1700	12.3
4/28/75*	0115-0330	54.64	11/16/76§	1120-1240	15.3
6/12/75*	1300-1320	51.40	11/16/76§	1440-1555	13.0
6/12/75*	1513-1609	51.40			
			MINIMUM		12.3
			AVERAGE		43.84
			MAXIMUM		60.41

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 22.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 7.

§ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. Table 2, p. 21.

TABLE B-110. EPA METHOD 5 PARTICULATE LOADINGS OF SCRUBBER OUTLET GASES

DATE	TIME	PARTICULATE LOADING (g/dscm)	DATE	TIME	PARTICULATE LOADING (g/dscm)
2/21/75*	1920-2020	0.4279	7/18/75*	1142-1136	0.2792†
3/ 6/75*	1348-1448	0.3044	7/23/75*	1017-1217	0.1556†
3/13/75*	1415-1515	0.5812	7/24/75*	0956-1212	0.1281†
3/13/75*	1745-1845	0.8238	7/30/75*	1331-1729	0.3822†
4/ 9/75*	0145-0523	0.5835	6/ 9/76†	1713	0.6311
4/10/75*	1205-1342	0.3799	7/23/76†	1048	0.4275
4/18/75*	1730-2018	0.2174†	8/ 5/76†	0800	0.4064
4/27/75*	0411-0548	0.8165	8/ 5/76†	1145	0.3519
4/28/75*	0115-0330	0.5682	8/ 7/76†	1530	0.4538
4/28/75*	1242-1407	0.5538	8/ 7/76†	1542	0.1833
4/28/75*	1755-1950	0.7920	11/15/76†	1540-1700	0.6156
6/12/75*	1513-1609	0.4943†	11/16/76†	1120-1240	0.4714
7/17/75*	1716-1916	0.2906†	11/16/76†	1440-1555	0.5515

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 22.

† Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 7

§ TRW Environmental Engineering Division. Source Emissions Tests for Industrial Research Labs. EPA 68-01-2988, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. Table 2, p. 21.

†† Filter only.

TABLE B-111. ANDERSON PARTICLE SIZE ANALYSIS OF SCRUBBER OUTLET GASES

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
4/27/75*	0505	8.2	.220	21.65	4/28/75	1800	2.98	.053	4.74
		5.2	.002	0.52			1.89	.055	4.95
		3.4	0.0	0.0			0.98	.105	9.48
		2.36	.007	1.55			0.59	.176	15.88
		1.51	.014	3.09			0.41	.220	19.79
		0.78	.032	7.22			0.41	.119	10.72
		0.46	.085	19.07			9.2	.114	38.46
		0.31	.108	24.23			5.8	.009	3.08
		0.31	.101	22.68			3.8	0.0	0.0
		9.0	.195	42.29			2.7	.009	3.08
4/28/75*	0300	5.7	0.0	0.0	5/10/75+*	1640	1.68	.016	5.38
		3.7	0.0	0.0			0.87	.080	26.92
		2.6	0.0	0.0			0.52	.009	3.08
		1.65	0.0	0.0			0.36	.002	0.77
		0.86	.005	.995			0.36	.057	19.23
		0.51	.080	17.41			8.8	.229	54.95
		0.35	.050	10.95			5.7	0.0	0.0
		0.35	.130	28.34			3.7	0.0	0.0
		10.2	.114	32.68			2.6	.005	1.1
		6.4	.011	3.27			1.64	0.0	0.0
4/28/75*	1405	4.2	.011	3.27	5/12/75+*	0200	0.85	.011	2.75
		2.91	.002	.654			0.50	.016	3.85
		1.85	.011	3.27			0.35	.057	13.74
		0.95	.011	3.27			0.35	.098	23.67
		.57	.048	13.73			10.0	.275	45.28
		.40	.066	18.95			6.2	.005	0.76
		.40	.073	20.92			4.1	.009	1.51
		10.6	.281	25.36			2.8	.005	0.76
		6.5	.046	4.12			1.81	.018	3.02
		4.4	.055	4.95			0.94	.023	3.77
4/28/75*	1800				5/12/75+*	1210			

TABLE B-111. (Continued)

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
5/12/75†*	1210	0.55	.030	4.91	5/31/75*	1558	8.6	.178	46.15
		0.39	.108	17.74			5.4	0.0	0.0
5/12/75†*	1930	0.39	.135	22.26			3.6	0.0	0.0
		9.6	.281	49.4			2.4	.002	0.59
		6.1	.018	3.21			1.56	.002	.59
		4.0	.014	2.41			.80	.018	4.73
		2.8	.023	4.02			.47	.050	13.02
		1.75	.039	6.83			.33	.101	26.04
		0.92	.027	4.82			.33	.037	9.47
		0.54	.057	10.04	6/01/75*	2035	8.7	.222	45.75
		0.38	.041	7.23			5.6	.007	1.42
		.038	.069	12.05			3.6	.007	1.42
5/30/75*	1535	9.4	.133	43.94			2.5	.005	.94
		5.9	0.0	0.0			1.62	.011	2.36
		3.9	0.0	0.0			0.84	.016	3.30
		2.7	0.0	0.0			0.49	.082	16.98
		1.72	0.0	0.0			0.34	.094	19.34
		.89	.007	2.27			0.34	.041	8.49
		.53	.034	11.36	6/02/75*	1532	8.6	.215	40.34
		.37	.073	24.24			5.5	0.0	0.0
		.37	.055	18.18			3.5	.011	0.21
5/30/75*	2045	9.5	.094	30.83			2.5	.011	0.21
		6.0	.011	3.76			1.57	.009	1.72
		3.9	.011	3.76			0.81	.016	3.00
		2.7	.009	3.01			0.48	.101	18.88
		1.72	.009	3.01			0.33	.135	25.32
		0.90	.016	5.26			0.33	.055	10.30
		0.53	.034	11.28	6/12/75*	1625	8.9	.339	39.36
		0.37	.069	22.56			5.6	.005	1.53
		0.37	.050	16.54			3.6	.003	0.27

TABLE B-111. (Continued)

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
6/12/75*	1625	2.5	0.0	0.0	6/20/75*	0828	.52	.025	9.17
		1.62	.034	3.99					
		0.83	.085	9.84					
		0.49	.197	22.87					
		0.35	.153	17.82					
6/13/75*	1600	0.35	.046	5.32	6/27/75*	2020	7.6	.093	26.62
		10.8	.114	30.67					
		6.7	0.0	0.0					
		4.5	0.0	0.0					
		3.1	.007	1.84					
		1.95	.009	2.45					
		1.01	.023	6.13					
		0.61	.059	15.95					
		0.42	.012	31.29					
		0.42	.160	11.66					
6/16/75*	1900	9.5	.203	45.15	6/28/75*	1705	7.8	.108	30.13
		6.0	0.0	0.0					
		3.9	0.0	0.0					
		2.7	0.0	0.0					
		1.72	.002	0.49					
		.89	.014	2.91					
		.53	.039	8.25					
		.37	.101	21.36					
		.37	.103	21.84					
		9.2	.073	10.83					
6/20/75*	0828	5.8	0.0	0.0	7/02/75*	0730	5.0	.009	2.56
		3.8	.002	.83					
		2.7	.007	2.5					
		1.69	.009	3.33					
		.87	.018	6.67					
		9.2	0.0	0.0					
		5.8	.002	.83					
		3.8	.007	2.5					
		2.7	.009	3.33					
		.87	.018	6.67					

TABLE 5-111. (Continued)

Date	Time	Effective Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
7/02/75*	2015	8.8	.121	43.44	7/12/75*	1930	3.5	.021	8.18
		5.6	.002	0.82			2.4	.007	2.73
		3.6	.007	2.46			1.53	.009	3.64
		2.5	.007	2.46			0.79	.009	3.64
		1.62	.002	6.82			0.47	.027	10.91
		0.84	.014	4.92			0.32	.053	20.91
		0.50	.016	5.74			0.32	.055	21.54
		0.35	.041	14.75	7/17/75*	1750	8.5	.069	17.54
		.35	.069	24.59			5.4	.007	1.75
7/09/75*	1908	7.2	.078	16.19			3.5	.009	2.34
		4.6	0.0	0.0			2.4	.018	4.68
		3.0	.002	0.48			1.55	.014	3.51
		2.1	.007	1.43			0.80	.027	7.02
		1.36	.023	4.76			0.47	.069	17.54
		0.70	.046	9.52			0.33	.124	31.58
		0.40	.165	34.92			0.33	.055	14.04
		0.28	.126	26.19	7/17/75*	1845	8.5	.032	23.03
		0.28	.034	7.14			5.4	.002	0.56
7/12/75*	0815	9.2	.117	35.42			3.5	.002	0.56
		5.8	.009	2.71			2.4	.069	1.69
		3.8	.002	0.69			1.55	.014	2.81
		2.6	.005	1.39			0.80	.066	16.29
		1.68	.016	4.86			0.47	.105	25.84
		0.87	.007	2.08			0.33	.094	23.03
		0.51	.027	8.33			0.33	.025	6.19
		0.36	.053	15.97	7/17/75*	1950	8.3	.055	11.94
		0.36	.094	28.55			5.3	.002	0.50
7/12/75*	1930	8.2	.071	28.18			3.5	.032	6.97
		5.2	.007	.27			2.6	.050	10.95

TABLE B-111. (Continued)

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
7/17/75*	1950	1.55	.021	4.48	7/18/75*	1345	0.44	.126	33.54
		0.80	.032	6.97			0.31	.213	23.17
		0.47	.117	25.37			0.31	.025	6.70
		0.32	.112	24.38	7/19/75*	1219	8.2	.062	23.68
		0.32	.039	8.44			5.3	0.0	0.0
7/18/75*	1144	7.9	.057	16.56			3.4	0.0	0.0
		5.0	.007	1.99			2.3	.002	.88
		3.3	.007	1.99			1.52	.009	3.51
		2.3	.009	2.65			0.77	.018	7.02
		1.47	.011	3.31			0.46	.055	21.05
		0.75	.037	10.60			0.31	.066	25.44
		0.44	.080	23.18			0.31	.048	18.42
		0.31	.098	28.48	7/23/75*	1055	8.1	.039	16.35
7/18/75*	1220	0.31	.039	11.24			6.2	.002	0.96
		7.9	.064	13.08			3.3	.002	0.96
		5.1	.009	1.87			2.3	.002	0.96
		3.3	.009	1.87			1.51	.007	2.88
		2.3	.018	3.74			0.78	.030	12.50
		1.46	.021	4.21			0.45	.073	30.77
		0.75	.027	5.61			0.31	.039	16.35
		0.44	.092	18.69	7/23/75*	1128	0.31	.043	18.27
		0.31	.114	23.36			8.0	.043	24.05
7/18/75*	1345	0.31	.135	27.57			5.1	0.0	0.0
		7.9	.059	15.85			3.4	0.0	0.0
		5.0	.002	0.61			2.3	.005	2.53
		3.3	.005	1.22			1.48	.007	3.80
		2.3	.011	3.05			0.76	.014	7.59
		1.47	.016	4.27			0.45	.039	21.52
		0.75	.043	11.59			0.31	.046	25.32

TABLE B-111. (Continued)

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
7/23/75*	1128	0.31	.027	15.19	7/29/75*	2135	5.2	.004	1.92
7/23/75*	1200	8.2	.060	31.46			3.4	.002	1.08
		5.2	0.0	0.0			2.3	.008	4.20
		3.4	.0007	0.36			1.5	.002	1.08
		2.4	.002	1.20			0.77	.009	4.56
		1.52	.005	2.39			0.45	.057	29.89
		0.78	.014	7.18			0.31	.060	31.33
		0.46	.050	26.32			0.31	.013	6.73
		0.32	.043	22.73	7/30/75*	1430	8.2	.103	24.46
		.32	.016	8.36			5.2	.003	0.65
7/25/75*	1808	7.3	.055	20.9			3.4	.0005	0.11
		4.7	.005	2.07			2.4	.004	1.03
		3.0	.005	2.07			1.51	.013	3.21
		2.1	.006	2.16			0.78	.002	5.65
		1.36	.005	1.73			0.46	.134	31.79
		0.69	.050	18.83			0.31	.113	26.79
		0.40	.103	38.77			0.31	.027	6.31
		0.28	.032	11.92	7/30/75*	1600	8.2	.078	19.64
		0.28	.004	1.55			5.2	.003	0.69
7/29/75*	2057	7.9	.050	19.84			3.4	.004	0.92
		5.1	0.0	0.0			2.3	.008	2.14
		3.3	.002	0.91			1.51	.010	2.54
		2.3	.004	1.46			0.78	.036	9.01
		1.46	.005	2.01			0.46	.133	33.62
		0.75	.018	7.31			0.31	.101	25.53
		0.44	.080	31.99			0.31	.023	5.91
		0.31	.069	27.51	7/23/76†§	1429	7.75	.066	24.17
		0.31	.022	8.97			4.95	.002	.83
7/29/75*	2135	8.1	.037	19.21			3.23	.002	.83

TABLE B-111. (Continued)

Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)	Date	Time	Effective Cut Diameter (micrometers)	Dry Loading (g/DSCM)	Weight (%)
7/23/76§	1429	2.23	.002	.83	8/05/76§	1010	0.46	.108	23.28
		1.44	.002	.83					
		.74	.011	4.17					
		.44	.057	20.83					
8/05/76§	1010	.30	.078	28.33	8/05/76§	1352	8.38	.103	38.28
		.30	.053	19.18					
		8.09	.137	29.51					
		5.16	0.0	0.0					
		3.36	.004	0.79					
		2.33	.005	0.99					
		1.50	.009	2.03					
		.0.77	.025	5.44					
							.32	.029	8.89

* Herrington, R. C., D. E. Honaker, and B. G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7240. St. Louis, Missouri, 1976. Table 18.

† Not corrected to 12 percent CO₂.

§ Herrington, R. C., T. F. Buss, and D. E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc. No. 7250. St. Louis, Missouri, 1976. Table 9.

TABLE B-112. BMS-11 PARTICULATE SIZE ANALYSIS OF SCRUBBER OUTLET*

DATE	TIME	EFFECTIVE CUT DIAMETER $\rho=1$ (MICRONS)	EFFECTIVE CUT DIAMETER $\rho=2.4$ (MICRONS)	WT. %	DATE	TIME	EFFECTIVE CUT DIAMETER $\rho=1.0$ (MICRONS)	EFFECTIVE CUT DIAMETER $\rho=2.4$ (MICRONS)	WT. %
4/10/75	0356	2.60-10.0	1.70-7.00	13.04	5/12/75	1150	>3.72	>2.37	0.247
		1.50-2.60	0.99-1.70	36.92			2.20-3.72	1.39-2.37	1.485
		1.00-1.50	0.66-0.99	37.20			1.51-2.20	0.95-1.39	2.228
		0.50-1.00	0.30-0.66	4.30			0.81-1.51	0.49-0.95	10.891
		0.20-0.50	0.13-0.30	7.17			0.50-0.81	0.295-0.49	8.663
4/10/75	1330	<0.20	<0.13	1.36	5/12/75	1910	<0.50	<0.295	54.700
		2.60-10.0	1.70-7.00	17.03			>4.44	>2.84	2.43
		1.50-2.60	0.99-1.70	34.24			2.64	1.68	1.62
		1.00-1.50	0.66-0.99	13.40			1.82	1.14	6.88
		0.50-1.00	0.30-0.66	15.94			0.97	0.60	2.43
5/12/75	0152	0.20-0.50	0.13-0.30	19.38	5/15/75	1652	0.63	0.38	13.77
		<0.20	<0.13	-			<0.63	<0.38	49.79
		>4.47	>2.86	0.095			>3.98	>2.53	-
		2.66-4.47	1.68-2.86	0.095			2.35	1.48	-
		1.83-2.66	1.15-1.68	0.285			1.60	1.00	6.57
		0.98-1.83	0.60-1.15	2.484			0.83	0.50	9.98
		0.63-0.98	0.38-0.60	2.381			0.51	0.29	3.29
		<0.63	<0.38	89.544			<0.51	<0.29	4.07

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 21.

TABLE B-113. ANALYSIS OF SCRUBBER OUTLET PARTICULATE*

DATE TIME	METHOD	7/17/75 1716-1916	7/18/75 1142-1336
Weight of Solubles			
Weight of Total Part.		0.2676	0.2578
% Soluble		0.2905	0.2860
Chloride (%) Cl ⁻	Ion Selective Electrode	92 47.14	90 45.08
Fluoride (%) F ⁻ (µg/g)	Ion Selective Electrode	0.10	0.18
Bromide (%) Br ⁻	Ion Selective Electrode	(96.50) 1.06	(175.50) 1.53
Ammonium (%) NH ₄ ⁺ (µg/g)	Ion Selective Electrode	0.97	0.64
Sulfate (%) SO ₄ ²⁻	Phototurbidimetric Method	(968) 9.13	(643) 13.12
Sulfite (%) SO ₃ ²⁻	Polarography	ND	ND
Carbonate (%) CO ₃ ²⁻	Gravimetric Means	1.26	1.81
Nitrate (%) NO ₃ ⁻	Colorimetric Method	0.038	0.073
Cyanide (%) CN ⁻	Ion Selective Electrode Using	<0.02 if any	<0.02 if any

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 23.

TABLE B-114. ELECTRON PROBE MICRO ANALYSIS OF SCRUBBER OUTLET PARTICULATE*†

SIZE RANGE (MICRONS)	>9.40	5.90- 9.40	3.90- 5.90	2.70- 3.90	1.70- 2.70	0.90- 1.70	0.50- 0.90	0.40- 0.50	<0.40
PERCENT BY WEIGHT									
TOTAL	43.90	--	--	--	--	2.27	11.36	24.74	18.18
ALUMINUM	--	--	--	--	--	0.02	9.02	0.02	--
CALCIUM	3.20	3.00	3.20	3.80	4.50	4.60	2.80	1.90	8.10
COPPER	0.10	0.10	1.10	1.00	4.10	5.20	24.00	27.00	2.20
IRON	0.20	0.10	0.80	1.10	2.50	2.50	2.10	2.20	0.30
LEAD	0.10	0.10	0.10	1.00	4.10	5.20	24.00	27.00	2.20
MAGNESIUM	0.80	1.00	0.40	0.50	1.00	0.60	0.40	0.10	1.40
SILICON	12.70	12.10	15.00	8.70	5.80	5.00	0.60	0.40	14.80
SODIUM	2.00	1.80	9.00	2.20	4.20	5.30	1.70	1.80	2.40
TITANIUM	--	--	--	0.20	0.90	1.30	0.10	0.05	0.10
ZINC	--	0.02	0.10	0.03	0.10	2.30	3.90	3.30	0.10

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc., No. 7240. St. Louis, Missouri, 1976. Table 29.

†Collected 5/30/75 at 1535.

TABLE B-115. DEHUMIDIFIER BAY TEMPERATURE AND VELOCITY DATA*

BAY NO.	MEAN TEMPERATURE (°C)	MEAN VELOCITY (MPM)	FLOW RATE (ACMM)	FLOW RATE (DSCM@21°C)
1	49.50	338.3	4526.7	2113.9
2	49.35	232.9	4333.0	2024.3
3	49.37	280.8	3757.7	1755.5
4	48.71	287.0	3840.2	1797.7
5	49.07	338.7	4531.2	2118.8
6	50.16	334.2	4471.3	2083.7

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems, Inc., No. 7240. St. Louis, Missouri, 1976. Tables 20 and 30.

TABLE B-116. MASS SPECTROPHOTOMETRIC ANALYSIS OF DEHUMIDIFIER GASES* (VOLUME %)

Date	7/24/75	7/24/75
Time	--	--
Carbon Dioxide	0.59	0.61
Argon	0.73	0.73
Carbon Monoxide	0.21	0.12
Oxygen	20.45	20.38
Nitrogen	78.00	78.15
Methane	--	--
Hydrogen	--	--

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem System Inc., No. 7240. St. Louis, Missouri, 1976. Table 31.

TABLE B-117. ANDERSON PARTICLE SIZE ANALYSIS OF DEHUMIDIFIER MINISTACK*

DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADINGS (g/DSCM)	WEIGHT (%)	DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADINGS (g/DSCM)	WEIGHT (%)
4/22/75	0910	7.80	0.053	23.71	4/27/75	0558	0.89	0.062	11.95
		5.00	0.014	6.91			0.53	0.130	25.22
		3.20	0.000	0.00			0.37	0.126	24.34
		2.20	0.009	4.12			0.37	0.034	6.64
		1.44	0.039	17.53			9.40	0.048	19.27
		0.73	0.021	9.28			6.00	0.000	0.00
		0.43	0.021	9.28			3.90	0.006	2.75
		0.30	0.032	14.43			2.76	0.032	12.84
		0.30	0.034	15.46			1.74	0.000	0.00
		8.20	0.172	29.18			0.90	0.014	5.50
4/22/75	2250	5.30	0.002	0.39	4/28/75	0354	0.54	0.062	24.77
		3.50	0.039	6.61			0.37	0.000	0.00
		2.40	0.014	2.33			0.37	0.087	34.87
		1.52	0.046	7.78			9.40	0.112	29.70
		0.79	0.160	27.24			5.90	0.007	1.82
		0.46	0.103	17.51			3.90	0.002	0.61
		0.32	0.041	7.00			2.66	0.016	4.24
		0.32	0.011	1.96			1.71	0.016	4.24
		9.40	0.300	5.75			0.88	0.034	9.09
		5.90	0.021	3.98			0.53	0.124	32.73
4/27/75	0558	3.90	0.037	7.08	4/28/75	0455	0.37	0.050	13.33
		2.70	0.037	7.08			0.37	0.016	4.24
		1.71	0.041	7.96			9.20	0.087	15.38

(continued)

TABLE B-117. (Continued)

DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADINGS (g/DSCM)	WEIGHT (%)	DATE	TIME	EFFECTIVE CUT DIAMETER (MICRONS)	DRY LOADINGS (g/DSCM)	WEIGHT (%)
4/28/75	0455	5.90	0.080	14.17	4/28/75	1940	0.96	0.053	60.53
		3.80	0.053	9.31			0.57	0.153	35.34
		2.68	0.053	9.31			0.40	0.178	6.02
		1.69	0.034	6.07			4.00	0.037	0.00
		0.87	0.071	12.55			9.80	0.000	0.00
	1355	0.52	0.057	10.12		5/15/75	6.20	0.000	0.00
		0.36	0.098	17.41			4.10	0.000	0.00
		0.36	0.032	5.68			2.80	0.000	0.00
		9.80	0.064	12.12			1.79	0.011	1.21
		6.10	0.032	6.06			0.72	0.014	1.46
4/28/75	1940	4.00	0.050	9.52	5/15/75	1711	0.55	0.796	84.47
		2.78	0.016	3.03			0.38	0.096	10.19
		1.77	0.037	6.93			0.38	0.025	2.67
		0.91	0.073	13.85			7.50	0.043	12.58
		0.55	0.130	24.68			4.80	0.011	3.31
	1940	0.38	0.089	16.88			3.10	0.016	4.64
		0.38	0.037	6.93			2.20	0.014	3.97
		10.20	0.059	90.23			1.39	0.018	5.30
		6.40	0.018	87.22			0.71	0.055	15.89
		4.20	0.069	75.94			0.42	0.12	32.45
4/28/75	1940	2.90	0.021	72.56			0.29	0.066	19.21
		1.85	0.021	69.18			0.29	0.009	2.65

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 32.

TABLE B-118. ELECTRON PROBE MICRO ANALYSIS
(E.P.M.) OF DEHUMIDIFIER PARTICULATE*

SIZE RANGE (MICRONS)	>8.20	5.20- 8.20	3.40- 5.20	2.50- 3.40	1.60- 2.50	0.80- 1.60	0.50- 0.80	0.30- 0.50	<0.30
PERCENT BY WEIGHT									
Total	18.20	0	2.60	11.70	0	5.20	23.40	0	38.90
Calcium	2.70	3.60	3.70	3.70	3.30	3.00	0.90	1.30	2.60
Chloride	0.01	0.20	0.60	2.30	6.40	4.10	12.80	14.40	8.40
Copper	0.02	--	--	--	0.10	0.20	0.30	0.50	0.20
Chromium	--	--	0.10	--	0.10	--	--	0.10	0.10
Iron	0.10	0.04	0.06	0.10	0.40	0.40	0.30	0.50	0.20
Lead	0.10	0.02	0.20	0.30	2.20	1.60	4.40	4.90	5.70
Phosphorous	0.03	--	0.20	--	0.10	--	0.10	0.05	0.10
Potassium	0.10	0.20	0.80	1.10	2.70	1.80	2.60	3.80	2.70
Silicon	4.30	9.50	17.60	22.20	12.60	8.90	0.60	1.00	2.20
Sodium	1.00	2.30	6.70	14.30	6.50	4.90	6.80	5.20	7.20
Sulfur	0.10	0.10	0.10	0.30	0.70	0.90	0.40	0.50	0.30
Tin	--	--	--	--	--	--	--	--	--
Zinc	0.03	0.20	0.02	0.10	2.70	2.40	2.70	1.70	1.40

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No 7240. St. Louis, Missouri, 1976. Table 33.

TABLE B-119. DEHUMIDIFIER CONDENSATE FLOW

DATE	TIME	FLOW l/min. (D.H. Fans On)	FLOW l/min. (D.H. Fans Off)
11/16/76*		151	
11/26/76*		113	
11/27/76*		182	
11/29/76*		216	
12/ 7/76*		175	
12/ 7/76	0310	155	
12/ 9/76	2000	185	
12/10/76		156	
12/10/76	1130	152	
	1715	166	
12/12/76	1230	166	
12/13/76*		156	
12/13/76	1015	189	
	1315	182	
	1635	197	
	1805	163	
12/14/76	0945		27
	1230		35
	1605		31
12/15/76	0930		38
	1745	98	
12/16/76	1015		49
12/17/76	0940		32
1/11/77*		189	
1/13/77*			19
1/13/76	1630		21
1/14/77	1020		25
1/31/77	0930	112	
2/ 1/77	1230		30
	1430		29
Average		163.3	30.5

* Monsanto Field Data , unpublished.

TABLE B-120. ANALYSIS OF DEHUMIDIFIER CONDENSATE

Date Time	7/17/78* 1730 (mg/l)	8/6/75+ 1145 (mg/l)	8/6/75+ 1400 (mg/l)	12/7/76 (mg/l)	2/1/77 1500 (mg/l)	3/1/77 (mg/l)	4/28/77 1630 (mg/l)	Average (mg/l)
Acidity				2450	2900	23,900	5250	8625
Alkalinity, CO ₃	24							24
Ammonia	2.4							2.4
BOD ₅				3.5				3.5
Bromide	10							10
COD				26				26
Chloride	249.95	560	530	1995	1380	32,200	36,000	10416
Flouride	0.75							0.75
Hardness		360	587					475
Iron					610	4650		2530
Lead						360	200	280
Mercury						3.8	0.056	1.9
Nitrate		2.64	3.43					2.925
Total Kjeldahl Nitrogen				1				1
Phosphate	1.0	0.07						0.535
Phosphorous, Total				25				25
Sulfate	150	424	430			4470	2460	1587
Sulfide						11.6	0.8	6.2
Sulfite						0.0		0.0

*Herrington, R.C., D.E. Honaker, and B.G. Ward. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 43.

†Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7240. St. Louis, Missouri, 1976. Table 14.

TABLE B-121. MOISTURE CONTENT OF VARIOUS RESIDUE RECOVERY PROCESS STREAMS*

DATE	TIME	SAMPLE	% MOISTURE
6/8/76	2220	Glass Settling Box	57.8
6/9/76	0000	Char	54.1
		Oversized Floats	77.4
		Glassy Aggregates	28.8
	2100	Char	48.2
		Residue	29.4
		Glass Settling Box	70.1
		Glassy Aggregates	30.0
		Oversized Aggregates	41.2
		Oversized Floats	47.9
6/11/76	0515	Residue	32.0
6/25/76	1000	Residue	59.2
7/21/76	1400	Residue	29.1
	1900	Residue	20.0
7/22/76	1300	Residue	19.0
7/23/76	1600	Residue	17.3
	1800	Residue	17.6
8/5/76	1030	Residue	15.2
8/6/76	1330	Flotation Separator Sinks	23.4
		Glassy Aggregates	14.7
		Oversized Floats	75.7
		Flume Screen	73.2

*Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976. Table 18.

TABLE B-122. SOLIDS ANALYSIS OF VARIOUS RESIDUE RECOVERY PROCESS STREAMS*

DATE	TIME	SAMPLE	pH	TDS (mg/l)	TSS (mg/l)
6/9/76	0000	Thickener Underflow	10.86	1,546	74,307
		Thickener Inlet	9.03	1,080	3,207
	2100	Thickener Underflow	9.02	1,376	1,886
		Thickener Overflow	9.15	1,146	95
		Thickener Underflow	10.90	1,749	52,449
		Vacuum Filter Filtrate	9.25	343	12,630
8/7/76	1400	Flotation Separator Overflow	9.35	2,344	1,163
		Glass Settling Box In	9.34	370	35,480
	1500	Glass Settling Box Out	8.84	259	811

*Herrington, R.C., T. F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976. Table 18.

TABLE B-123. PROXIMATE AND ULTIMATE ANALYSIS OF CHAR*

DATE TIME	6/9/76 0000		8/7/76 1500		8/7/76 1900	
	AS REC'D	DRY	AS REC'D	DRY	AS REC'D	DRY
Moisture (%)	58.96	---	40.12	---	44.89	---
Volatile Matter (%)	4.71	11.48	8.12	13.57	4.98	9.04
Fixed Carbon (%)	14.98	36.49	16.32	27.25	7.65	13.85
Ash (%)	21.35	52.03	35.43	59.18	42.50	77.11
Sulfur (%)	0.14	0.34	0.16	0.27	0.12	0.22
Btu's/KG	5398	12,155	5593	9344	3439	6239
Carbon (%)	---	39.79	---	31.37	---	17.96
Hydrogen (%)	---	1.04	---	1.23	---	0.60
Nitrogen (%)	---	1.66	---	0.57	---	0.40
Oxygen (%)	---	6.14	---	7.38	---	3.71

*Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc., No. 7250. St. Louis, Missouri, 1976. Table 19.

TABLE B-124. PROXIMATE AND ULTIMATE ANALYSIS OF GLASSY AGGREGATES*

DATE TIME	6/9/76 0000		8/7/76 1400	
	AS REC'D	DRY	AS REC'D	DRY
Moisture (%)	29.68	---	21.61	---
Volatile Matter (%)	1.70	2.33	1.77	2.25
Fixed Carbon (%)	1.76	2.41	1.07	1.37
Ash (%)	68.82	94.26	75.55	96.38
Sulfur (%)	0.04	0.05	---	---
MJ/kg	.03	.04	---	---
Carbon (%)	---	4.21	---	2.52
Hydrogen (%)	---	0.47	---	0.14
Nitrogen (%)	---	0.16	---	0.08
Oxygen (%)	---	0.85	---	0.85

*Herrington, R.C., T.F. Buss, and D.E. Honaker. Baltimore Landgard® Process Characterization. Monsanto EnviroChem Systems Inc. No. 7250. St. Louis, Missouri, 1976. Table 19.

APPENDIX C

ECONOMIC EVALUATION

SECTION C-1

INTRODUCTION

BACKGROUND AND PURPOSE

In this section Arthur Young & Company, an accounting firm that was sub-contracted to perform the economic evaluation, describes the nature of the costs associated with the construction and operation of the Landgard system and presents costs projections on various plant operating and system characteristics. The presentation of costs is in accordance with the Office of Solid Waste Management Program's Accounting Format. To achieve a clear understanding of the organization of the section the reader should first familiarize himself with this format since it describes the manner in which cost data on resource recovery systems should be presented.

The EPA Accounting Format was developed to facilitate economic comparisons of resource recovery systems. Accordingly, two formats are designed which reflect "actual" and "normalized" resource recovery system costs and revenues. The normalized accounting format removes the site specific aspects of the parameters affecting plant costs (e.g., cost of land, labor rate) and compensates for varying local conditions. The actual accounting format is designed to reflect costs and revenues of a resource recovery system incorporating the site-specific parameters. Thus, the latter format captures the actual costs and revenues.

The standardized accounting format consists of three components: capital costs, operating and maintenance costs, and revenues. The capital costs format categorizes cost by land, site preparation, design, construction, real equipment, other equipment, contingencies, start-up and working capital, and finance and legal costs. The operating and maintenance format categorizes costs by salaries, employee benefits, fuel, electricity, water and sewer, maintenance, replacement equipment, residue removal, other overhead, taxes and licenses, insurance, management fees, and professional services. The revenue format categorizes revenues by recovered material. Definitions of the subcategorizations are contained in EPA's Accounting Format (Section C-7). It should be clearly understood that the guidelines and classifications of costs do not conform to Generally Accepted Accounting Principles (GAAP). This is discussed at length in Section C-8.

The accumulation of costs and revenues from the above formats yield the following outcomes:

- o Average annual capital costs
- o Capital cost per throughput ton

- o Total annual operating and maintenance costs
- o Operating and maintenance costs per ton
- o Total revenues per throughput ton
- o Net operating cost/profit

In addition, in accordance with the Request for Proposal, capital and operating and maintenance costs are allocated to seven cost centers. The cost centers correspond to major subsystems: Receiving; Size Reduction; Storage and Recovery; Thermal Processing; Energy Recovery; Residue Separation; and General Plant. Thus, an additional outcome is the derivation of respective subsystem costs.

Due to the erratic operating status of the plant and continuing equipment modifications, certain major adjustments to the approach were utilized in the economic evaluation. Three hypothetical operating scenarios were derived by SYSTECH and utilized by Arthur Young & Company to support the accumulation and projection of capital and operating costs. These scenarios account for the inoperation of specific subsystems (i.e., the material recovery and gas scrubber system) and the necessity for specific plant improvements (i.e., the electrostatic precipitator). Additionally, the scenarios compensate for the limited and erratic operating status of the plant by providing projected costs and revenues based on varying degrees of plant operating reliability. Thus, the accounting formats depict projected versus actual costs and revenues.

The scenario parameters presented regarding plant operating status have been determined by utilizing the actual operating history of the Baltimore Landgard plant with operating experience from other industrial plants of similar character. As in any projection, the estimates for Scenarios 2 and 3 are aimed at showing potential operating capabilities of the plant and should be considered as order of magnitude values.

The scenarios are primarily distinguished by their varying operating status. The first scenario's operating status corresponds to the plant's performance during the November 1976 to July 1977 period and is characterized by frequent plant shutdowns. The second scenario's operating status is based on an expanded operating staff and more efficient administrative procedures. It is estimated that the above changes in plant operation can increase by more than twofold the average continuous plant operating period. The third scenario's estimates are based on the most optimistic operating conditions likely to occur given the projected equipment improvements presently being initiated. As a result, it represents the highest continuous plant operating period which is based on expected improvements in plant reliability. In the discussion on operating and maintenance costs, the manner in which scenario parameters were derived is further explained.

SECTION C-2

DESCRIPTION OF THE ACCOUNTING SYSTEM

INTRODUCTION

Originally it was intended that all plant capital and operating and maintenance costs would be derived from the City of Baltimore's accounting system. Capital costs were largely derived in this manner (modifications to capital costs were made to account for expected subsystem replacements). However, operating and maintenance costs were derived based on projected plant operating scenarios. This approach was adopted due to the City's modified accrual accounting system and the erratic operation of the plant during the demonstration period.

Presented here is a description of the City's accounting system. Incompatibilities of the City's accounting system with EPA's format system cannot accurately depict operating and maintenance costs over a given period. In addition, the funds in use and chart of accounts (cost categories under each fund) are described, with accounts comprising costs related to the Pyrolysis Plant specifically delineated.

The City's accounting system is organized and operated on a fund basis which is typical of a municipality. In the accounting sense, a fund is defined as an independent fiscal and accounting entity with a self balancing set of accounts in which all financial activity related to specific objectives is segregated and recorded. The segregation and recording of financial activity for specific objectives is performed in accordance with special regulations, restrictions, or limitations.

FUNDS IN USE

The City maintains several funds within its accounting structure including:

- o The General Fund which is used primarily to account for the expenditures of general government.
- o Special Revenue Funds which are used to account for particular revenues such as Federal Revenue Sharing and grants or funds assigned for specific purposes.
- o Debt Service Funds which account for the payment of interest of outstanding long-term City obligations.

- o Capital Project Funds in which capital outlays are recorded for the construction of various facilities.
- o Enterprise Funds which are maintained to account for those activities which are designed to be self sustaining or supporting. Examples of this type fund are the golf course, civic center, and water operation funds.
- o Intragovernment Service Funds which are used to account for those activities that essentially provide service to other governmental units such as a municipal postal operation, a central supply store, or a central laundry facility.
- o Trust and Agency Funds which account for those funds of others which are held in trust. An example is funds held to provide retirement benefits for the City employees.
- o Special Assessment Funds which are used to account for the activity of any levy made by the City which is meant to finance only a specific activity such as off-street parking facilities which are privately owned but City financed.

In addition to maintaining the above funds within the accounting system, the City also maintains a General Fixed Asset group of accounts and a General Long-Term Debt group of accounts. These accounts reflect the acquisition of tangible assets used to conduct the general functions of government, such as small item purchases, and the issuance and retirement of long-term debt instruments.

The financial activities which specifically relate to the construction and maintenance of the Baltimore Landgard plant, including grant funds received, are recorded in the General Fund and Capital Projects Fund.

BASIS OF ACCOUNTING APPLICABLE TO LANDGARD PROJECT

The City of Baltimore accounting records, and subsequently the financial statements, of the General Fund and Capital Projects Fund are maintained or prepared on a modified accrual basis of accounting. Under a modified accrual basis of accounting, revenues are recorded when received in cash, except revenues which are considered both measurable and available for current year appropriation financing. Expenses are recorded when liabilities are incurred, regardless of when an outflow of cash is experienced, except for accrual annual leave which is reflected in expenses when actually paid. As a result, operating and maintenance costs recorded during the given time period may not represent actual incurred costs. Rather, these costs may cover expenses attributed to other time periods. For example, fuel purchased in May would be expended in full for that period. However, the quantity purchased may cover a six month consumption period. Therefore, the fuel costs for May would be overstated.

CHART OF ACCOUNTS AND INTERNAL COST IDENTIFICATION

The City of Baltimore maintains a chart of accounts which permits varying degrees of cost/revenue identification depending on whether Balance Sheet (capital costs) or Income Statement (revenues and operating and maintenance costs) accounts are under consideration. The account format used by the City is as follows:

- o Operating Expense identification available through utilization of the chart of accounts consists of the following items with examples relating to the Pyrolysis Plant provided in parenthesis:
 - Fund (General Fund)
 - Department (Refuse Disposal)
 - Activity (Pyrolysis Plant)
 - Class of Expense (Operations, Maintenance and Repair, or General Expense)
 - Object of Expense (Salaries and Wages, Other Personnel Costs, Contractual Services, Materials and Supplies, Equipment Replacement, Additional Equipment)
 - Sub-object of Expense (i.e., Regular Salaries, Temporary Salaries, Overtime, Vacation/Leave, etc.)
- o Capital cost identification available through the system consists of the following, with examples relating to the Pyrolysis Plant provided in parenthesis:
 - Identification of capital projects fund (Sanitation)
 - Construction Program (Incinerator)
 - Project (Pyrolysis Plant)
 - Subprojects (Extra Work, Design and Studies, Site, Inspection, Structures and Improvement, Utilities, Furniture, and Equipment, General)
 - Sub-object (i.e., Salaries, Labor, Various Benefits, Test Borings, Advertising, Surveys, Demolition, Relocation, Paving, etc.)
- o Revenue from operation of the Pyrolysis Plant can be identified through the accounts as follows:
 - Revenues from sale of ferrous metals
 - Revenue from sale of steam

FINANCIAL REPORTS AND LEDGERS AVAILABLE

On a periodic basis, the City produces the following reports and ledgers:

- o The Annual Financial Report
- o The Monthly Financial Report (further discussed below)
- o Detailed Monthly Journals and Ledgers

The Monthly Financial Report is presented in three formats.

- o The Level I Report is a summary monthly financial statement at program level (Refuse Disposal)
- o The Level II Report is a cumulative summary financial statement with additional data provided such as method of Refuse Disposal (Pyrolysis Plant)
- o The Level III Report provides detailed data in the form of a listing of all transactions by program and each transaction for each program (e.g., Refuse Disposal), by activity (e.g., Pyrolysis Plant), object summary (e.g., Salaries and Wages), and sub-object (e.g., Regular Salaries)
- o In addition to the detailed Level III Report for operating expenses, a similar report entitled the Capital Expenditure Extract is prepared which details each transaction and cost over the life of a project. The Capital Expenditure Extract details transactions by capital project fund (e.g., Sanitation), by program (e.g., Incinerator), by project (e.g., Pyrolysis Plant), sub-projects (Design and Studies), and by sub-object (e.g., Consultants).

All costs relating to the Pyrolysis Plant were researched and accumulated from the Level III Report (operating and maintenance expenses) and the Capital Expenditure Extract.

GENERAL COMMENTS AND OBSERVATIONS OF CITY ACCOUNTING SYSTEM AS APPLICABLE TO LANDGARD

In relation to the determination of costs per EPA guidelines specific incompatibilities of the municipal accounting system include the following:

- o Costs are not accumulated by functional cost center as identified by EPA. This precludes accurate accumulation of costs for comparison of different waste recovery systems.
- o Transactions are recorded on a modified accrual basis rather than an Enterprise Fund. The modified accrual basis does not provide for a proper matching of revenue and expense. As a result, such transactions as the purchase of fuel is recorded as fully expensed in the period purchased, whether or not the quantities of fuel are consumed in total during that period. This creates distortions in recorded expenses.
- o Capital assets are not subject to depreciation, thereby under-yearly operating and maintenance expenses.

Currently, the City is accounting for the Landgard operating expenses under the General Fund on a modified accrual basis. In municipal accounting such activities are normally accounted for in an Enterprise Fund. Enterprise

Funds by their nature employ full accrual accounting procedures. A full accrual accounting system is one whereby revenues are recorded when earned and expenses are recorded when incurred. It is through this basis of accounting that a realistic and meaningful relationship between revenues and expenses can be developed. This proper matching of revenues and expenses is necessary for true net income or loss measurement to be achieved. Therefore, if an operation such as the Pyrolysis Plant were expected to pay at least in part for its operation through the sale of processing by-products, the full accrual basis of accounting would be most appropriate. If a full accrual system were employed, depreciation on the plant facilities would also be recorded as an expense over some estimated useful life of the facility, and through the Enterprise Fund, would be recognized as a bona-fide expense of doing business.

The above mentioned differences in accounting approaches (between EPA, municipal practices, and GAAP) should be carefully considered when comparing Landgard economics with those of other processes employing resource recovery from solid waste.

SECTION C-3

CAPITAL COSTS

INTRODUCTION

The most basic element in examining the economics of the Baltimore Landgard Plant is the determination of incurred costs. Every activity undertaken as part of the design, construction, and operation of the facility is included in these costs; and once these costs are determined they must be categorized as either capital costs or operating costs. In this section, capital costs relating to the Baltimore Landgard Plant are examined.

Capital costs of a waste treatment plant include the cost of such property or asset until it has been placed in position and properly operating. All costs incurred in placing an asset in this status are proper inclusions of the capital cost.

Once the capital costs incurred by the City of Baltimore were identified, they were classified according to EPA guidelines. The guidelines included two formats. The first format coincides with the Office of Solid Waste Management Program's Accounting Format (Section C-7). Under this format, capital costs are subcategorized as Land, Site Preparation, Design, Construction, Real Equipment, Other Equipment, Contingencies, Start up and Working Capital, and Financing and Legal.

The second format coincides with the seven EPA delineated cost centers (as cited in the Request for Proposal) which are:

- o Receiving
- o Size reduction
- o Storage and recovery
- o Thermal processing
- o Energy recovery
- o Residue separation
- o General plant

Each of the cost centers correspond to a plant subsystem, thus, providing for an economic analysis and comparison of subsystems costs.

The guidelines from the Accounting Format are not consistent with Generally Accepted Accounting Principles. The conditions and extent of the departure from Generally Accepted Accounting Principles are discussed in Section C-8.

METHODOLOGY

Costs billed for the Pyrolysis Plant were identified through examination of the City of Baltimore's accounting records. As previously described in the "Description of City Accounting System," capital expenditures related to the Pyrolysis Plant are charged to Capital Projects Fund accounts. All of Monsanto's Original Contract expenditures and most, but not all, of the Supplemental Agreement expenditures are contained in these accounts.*

Once expenditures relating to the capital costs were ascertained, a research and review of the Capital Extract listing was made. The Extract categorizes all expenditures by class description (i.e., Extra Work, Design & Studies, Site, Inspection, Structures, Utilities, Furniture and General; see Table C-1). Under each class description there is a cumulative listing of the voucher or check numbers which represent cost transactions. Through an examination of selected source documents relating to the voucher/check numbers, approximately 98 percent of the Extract costs were researched. Expenditures were investigated and scrutinized to determine whether they were (1) were properly chargeable to the project, (2) were properly classified as capital expenditures as opposed to operating expenses, (3) were materially accurate for reclassification per EPA guidelines and cost centers.

During the detailed review, certain adjustments to the reported amounts were necessary because certain operating and maintenance costs were charged as capital expenditures, and vice versa.

Additionally, certain costs were difficult to classify per EPA classifications, and as a result, some deviations to the EPA guidelines were necessary. These classification deviations included the following:

- o Site Preparation: The inclusion of the cost of improvements to the raw land including, but not limited to, roads, side walks, curbs, and landscaping; in addition to the specified costs of relocating present tenants and disposal site preparation.
- o Land: The inclusion of raw land and landscaping costs, in addition to land acquisition costs.

It was also ascertained that, due to insufficient data, many expenditures cannot be separated as to their Construction and Real Equipment components. To segregate costs by Construction and Real Equipment it is necessary to have access to engineering estimates which include the labor input factor per equipment item. However, this data was not available. This situation was particularly acute for expenditures related to the Supplemental Agreement. For the most part, the Supplemental Agreement invoices exhibited integrated cost items encompassing both Construction and Real Equipment.

*As of March 3, 1977, costs of \$404,593 which were incurred by Monsanto for the construction of the plant were not recorded in the Capital Expenditure Extract.

TABLE C-1. RESEARCH SUMMARY CAPITAL EXPENDITURE EXTRACT AS OF 3/31/77

<u>CLASS</u>	<u>DESCRIPTION</u>	<u>TOTAL</u>	<u>RESEARCHED</u>
#2	Extra Work	\$ 803,439	\$ 803,439
#3	Design & Studies	59,662	18,165
#4	Site	577,032	513,951
#5	Inspection	5,345	-0-
#6	Structures*	18,242,873	18,150,899
#7	Utilities	49,509	27,898
#8	Furniture & Equipment	3,199	-0-
#9	General	48,461	-0-
	Additional Equipment†	338,303	261,521
	Total	\$20,127,823	\$19,775,873

* As of 3/31/77 The Capital Expenditure Extract did not include approximately \$404,593 in unbilled costs incurred by Monsanto relating to the Supplemental Agreement.

† Recorded as Operating & Maintenance Expenses

The Monsanto Original Contract invoices were generally itemized (i.e., design, engineering, procurement, etc.). The invoices did not provide sufficient detail to identify or allocate costs to specific equipment items. Therefore, Original Contract allocation to cost centers were made on the basis of Monsanto's computer printout which delineated costs to equipment items from the generalized invoices.

The results of the capital cost analysis are illustrated in Tables C-2 and C-3. Table C-2 displays the costs in accordance with EPA Accounting Format. Table C-3 displays the costs in accordance with EPA's delineated cost centers.

As illustrated, the net capital costs in each exhibit are equal and total \$20,532,416. This results from adding the \$404,593 in unbilled costs incurred by Monsanto to the \$20,127,823 in costs recorded in the Capital Expenditure Extract (Table C-1).

EXCLUSIONS AND ADDITIONS

To facilitate economic comparison with other resource recovery systems, the capital costs were adjusted to state more accurately the costs that would be incurred if the plant were duplicated elsewhere. Therefore, as part of the financial review of the capital costs incurred on the Pyrolysis Plant, an investigation of certain cost exclusions and additions to the project were performed.

These adjustments account for the plant's experimental status, the inoperation and replacement of plant subsystems, and the inclusion of specified EPA cost elements not included in the Capital Expenditure Extract. The cost exclusions/additions relating to replaced and inoperative subsystems are consistent with the scenario parameter development by SYSTECH for the projection of operating and maintenance costs. A discussion of these additional adjustments follows.

Unique and Non-Recurring Costs

Unique costs attributable to the Baltimore Plant's status as a demonstration project would not recur if a similar facility were built elsewhere. These include costs of annual engineering services, research and development, extra shakedown costs, unanticipated construction modifications and additional performance testing.

An analysis of all recorded costs revealed that such unique and non-recurring costs were contained within Monsanto's Original Contract costs and Supplemental Agreement costs. Of the \$14,742,000 in Original Contract costs approximately \$1,648,649 (11.2 percent) were defined by Monsanto EnviroChem Systems as "Unique and Non-recurring" if a similar facility were built elsewhere. Monsanto's breakdown of the costs is as follows:

TABLE C-2. A SUMMARY OF EPA CAPITAL COST CLASSIFICATIONS

Title description	Land	Site preparation	Design	Construction	Real equipment	Other equipment	Financing and legal	Cost not researched	Total
#2 Extra work	--	\$121,343	\$11,500	\$194,243	\$380,854	\$95,499	--	--	\$803,439
#3 Design studies	--	--	18,165	--	--	--	--	\$41,497	59,662
#4 Site	\$486,411	27,540	--	--	--	--	--	63,081	577,032
#5 Inspection	--	--	--	--	--	--	--	5,345	5,345
#6 Structures and improvements:									
original contract	46,208	400,991	1,144,040	6,708,838	5,741,248	599,765	\$64,000	36,910	14,742,009
supplemental agreement	--	--	--	3,804,385	--	--	--	--	3,804,385
other costs	45,870	--	--	--	--	--	147	55,064	101,081
#7 Utilities	--	--	--	27,898	--	--	--	21,611	49,509
#8 Furniture and equipment	--	--	--	--	--	--	--	3,199	3,199
#9 General	--	--	--	--	--	--	--	48,461	48,461
Additional equipment	--	--	--	--	10,758	250,763	--	76,782	338,303
Total	578,489	549,874	1,173,705	10,735,364*	6,132,860†	946,027	64,147	351,950‡	20,532,416¶

* \$4,108,039 of these costs include both real equipment and construction costs that cannot be separated.

† \$371,587 of these costs include both real equipment and construction costs that cannot be separated.

‡ The \$351,950 represents costs not researched through examination of vouchers and is only 1.7% of the total costs.

¶ This sum includes \$404,593 of unbilled supplemental agreement costs.

TABLE C-3. SUMMARY COST CENTER DISTRIBUTIONS

Title descriptions	Receiving	Size reduction	Storage and recovery	Thermal processing	Energy recovery	Residue separation	General plant	Other costs*	Total
#2 Extra work	--	--	--	--	\$ 127,645	--	\$ 675,794	--	\$ 803,439
#3 Design and studies	--	--	--	--	--	--	18,165	\$ 41,497	59,662
#4 Site	--	--	--	--	2,840	--	511,111	63,081	577,032
#5 Inspection	--	--	--	--	--	--	--	5,345	5,345
#6 Structures and improvements:									
original contract	\$1,339,006	\$1,230,067	\$1,122,649	\$4,400,025	3,083,785	\$857,626	2,708,842	--	14,742,000
supplemental agreement	13,756	296,431	92,614	2,628,861	330,542	24,400	417,781	--	3,804,385†
other costs	--	--	--	--	--	--	46,017	55,064	101,081
#7 Utilities	--	--	--	--	--	--	27,898	21,611	49,509
#8 Furniture and equipment	--	--	--	--	--	--	--	3,199	3,199
#9 General	--	--	--	--	--	--	--	48,461	48,461
Additional equipment	2,605	5,547	--	2,606	--	17,941	232,822	76,782	338,303
Total	1,355,367	1,532,045	1,215,263	7,031,492	3,544,812	899,967	4,638,430	315,040	20,532,416

* Not researched or identified.

† This sum includes \$404,593 of unbilled supplemental agreement costs.

Development Cost	\$ 362,400
Pre-Contract Costs	270,000
Undeveloped Design Costs	152,000
Unanticipated Relocation and Modification Costs	610,000
Start-up and Training Costs	140,000
TOTAL COSTS	\$1,534,400
PROFIT*	\$ 114,249
TOTAL	<u>\$1,648,649</u>

Thus, all original contact costs were deflated by 11.2 percent to compensate for the inclusion of non-recurring costs attributable to the experimental status of the plant.

The Supplemental Agreement also contained cost items considered as unique, and non-recurring, and attributed to the plant's status as a demonstration project. Of the \$3,804,385 in Supplemental Agreement costs, \$3,084,517 of these costs were identified as non-recurring (unanticipated plant modification and replacement costs). The \$3,084,517 in non-recurring costs were derived through a detailed review of Supplemental Agreement expenditures. All cost items were classified as either exclusions or additions to the total project costs. Exclusions reflected those costs which, if corrective measures were taken, would not be duplicated elsewhere. For example, expenditures which covered defective design, incorrect placement, general repair costs, and replacement items were categorized as exclusions. Additions reflected costs which were recurring in nature. These included typical installation and procurement costs for the placement of assets in operation. All categorization of Supplemental Agreement costs were corroborated by the Plant Manager. In Section C-9, the categorization of Supplemental Agreement cost items are presented.

Contributed or Nominal Cost Items

Through inquiries and examinations of the plant's assets and the City of Baltimore's accounting records, no capital contributions were found to be associated with the project.

Residue Separation and Gas Scrubber Systems

Due to the nonfunctioning status of the residue separation and gas scrubber systems, the costs associated with these systems were deducted from total capital costs. First, all equipment items and their respective costs included in each of the system costs were identified. Once system costs were obtained, they were broken down by source (i.e., the Original Contract and Supplemental Agreement). To compensate for prior cost adjustments, the last

*This amount was imputed by Arthur Young & Company as the profit associated with the unique and non-recurring costs (11.2 percent of a total profit of \$1,021,600).

step involved the restating of costs to reflect the deflation of Original Contract costs and the Supplemental Agreement Cost exclusions.

Indirect costs associated with general plant expenditures that were included in the residue separation system costs have been deducted on a proportional basis. Since the electrostatic precipitator (ESP) is replacing the gas scrubber system, it was assumed that the general plant expenditures associated with the gas scrubber system would be reallocated to the ESP. The costs imputed for the residue separation and gas scrubber systems were \$1,031,218 and \$696,306, respectively.

Electrostatic Precipitator

The City of Baltimore has authorized funds to be expended for the construction of an electrostatic precipitator (ESP) to replace the gas scrubber system. As a result, plant capital costs were adjusted to reflect the cost of the ESP and the exclusion of the gas scrubber system. The cost of the ESP was estimated at \$2,571,500 based on City of Baltimore contract awards.

Residue Disposal

As required by the EPA Accounting Format, part of the total capital costs incurred for the Pyrolysis Plant were to include residue disposal costs. To accomplish this, it was necessary to determine the portion of the development costs of the appropriate landfill attributable to the Pyrolysis Plant.

Landfill costs were based on the cost and capacity of the City's current landfill servicing the Pyrolysis Plant, yielding a cost per cubic meter. By estimating the number of cubic meters necessary for the disposal of residue for the plant over its useful life, it was then possible to derive landfill costs. SYSTECH had recorded data on processed waste weight reduction and bulk density per cubic meter. A detailed description of how landfill costs were computed and allocated to the EPA classifications is contained in Section C-10.

The three operating scenarios affect landfill costs due to varying plant throughput rates. Subsequently, the amount of waste processed affects imputed residue disposal costs. As a result, three landfill disposal costs are presented.

Indirect Costs

As required by the EPA Accounting Format, all indirect costs attributable to the plant but not recorded in any formal manner were to be included in the total capital costs.

Indirect costs which were not recorded as part of the Pyrolysis Plant project consisted of financing and legal costs. Recorded within the City of Baltimore accounting records were approximately \$60,000 for this type expense. An examination of the \$60,000 in expenditures revealed that they did not

relate to the issuance of bonds. As a result of unrecorded bond finance and legal costs in the Capital Funds account for the Pyrolysis Plant, we imputed a cost utilizing a 2 percent rate suggested for normalization of costs in the EPA guidelines (also see EPA Financing, SW-1573, p. 14, Table 2). This rate was applied to the total capital costs for each of the three operating scenarios.

Although the City did not issue bonds for the total capital cost of the project, total costs were applied to the 2 percent rate to facilitate comparison with other resource recovery systems which do not receive State or Federal grants.

Restatement of Capital Costs in 1977 Dollars

In order to present plant replacement costs in the current year, all capital costs were restated in second quarter 1977 dollars. This methodology involved developing conversion factors for each cost segment (i.e., Original Contract, Supplemental Agreement, electrostatic precipitator, landfill costs, finance charges, and other costs) and applying these conversion factors to each cost segment's prior dollar amount. The conversion factors were derived from the Federal Reserve Composite Wholesale Industrial Index and the construction period of the cost segment (Table C-4). Table C-5 illustrates the impact of the exclusions and additions on total capital costs.

CLASSIFICATION OF COSTS PER EPA'S ACCOUNTING FORMAT

Capital costs incurred and subsequently adjusted were then classified according to EPA guidelines set forth in the "Accounting Format" (Section C-7). To complete EPA's capital cost format, the estimated useful life of the facility and total interest to be paid, had to be determined.

Estimated Useful Life of the Facility

The useful life of the facility was determined through reference to Internal Revenue Service guidelines for depreciable assets. The IRS depreciation regulations, as set out in Rev. Proc. 72-10, state that the useful life for solid waste disposal plants has a lower limit of 14.5 years. With due consideration given to the fact that the Pyrolysis Plant is experimental, the utilization of the lower limit useful life seems appropriate.

As a means of testing the validity of the 14.5 year useful life inquiries were made of select vendors. Table C-6 lists the results of the inquiry of respective vendors.

On a cost basis, the estimated useful life based on the above equipment items is between 17 and 18 years. This does not greatly differ from the IRS lower limit.

Interest to be Paid

The Baltimore Landgard project was primarily financed through:
(1) proceeds from the sale of City owned real estate which was designated

TABLE C-4. 1977 DOLLAR CONVERSION FACTORS

Composite Wholesale Industrial Index

Last quarter	1972	119.1
Last quarter	1973	130.3
Last quarter	1974	165.6
Last quarter	1975	175.4
Last quarter	1976	186.9
2nd quarter	1977	194.0

Conversion Factors

Factor to Restate Original Contract Costs:

$$\text{2nd quarter } 194.0 \div \{(199.1 + 165.6) \div 2\} = 1.36$$

Factor to Restate Supplemental Agreement Costs:

$$\text{2nd quarter } 194.0 \div \{(175.4 + 186.9 \div 2\} = 1.07$$

Factor to Restate Landfill Costs:

$$\text{2nd quarter } 194.0 \div 175.4 = 1.11$$

Factor to Restate Other Costs*

$$\text{2nd quarter } 194.0 \div \{(119.1 + 194.0 \div 2\} = 1.24$$

* Indicates all costs found in the Captial Extract not identified with Monsanto's Original Contract or Supplemental Agreement.

TABLE C-5. CAPITAL COSTS (EXCLUSIONS/ADDITIONS)

Calibration	Land	Site preparation	Design	Construction	Real equipment	Other equipment	Finance and legal	Other costs	Total capital cost
Costs before exclusions/additions	\$578,489	\$549,874	\$1,173,705	\$10,735,364	\$6,132,860	\$946,027	\$64,147	\$351,950	\$20,532,416
Original contract cost items restated	573,321	505,030	1,045,764	9,985,088	5,490,799	878,953	56,990	347,822	18,883,767
Supplemental agreement cost items restated	573,321	505,030	1,045,764	6,900,571	5,490,799	878,953	56,990	347,822	15,799,250
Exclusion of material recovery system costs	573,321	505,030	1,045,764	6,361,182	4,998,970	878,953	56,990	347,882	14,768,032
Exclusion of gas scrubber system costs	573,321	505,030	1,045,764	5,969,647	4,694,199	878,953	56,990	347,822	14,071,726
Inclusion of ESP costs	573,321	505,030	1,045,764	7,409,687	5,825,659	878,953	56,990	347,822	16,643,226
Inclusion of imputed landfill costs:									
Scenario 1	693,557	505,030	1,072,817	7,511,887	5,843,694	878,953	56,990	380,887	16,943,815
Scenario 2	935,056	505,030	1,127,154	7,717,161	5,879,919	878,953	56,990	447,299	17,547,562
Scenario 3	1,054,264	505,030	1,153,976	7,818,488	5,897,800	878,953	56,990	480,081	17,845,582
Inclusion of imputed finance charge:									
Scenario 1	693,557	505,030	1,072,817	7,511,887	5,843,694	878,953	395,866	380,887	17,282,691
Scenario 2	935,056	505,030	1,127,154	7,717,161	5,879,919	878,953	407,941	447,299	17,898,513
Scenario 3	1,054,264	505,030	1,153,976	7,818,488	5,897,800	878,953	413,902	480,081	18,202,494
Costs restated									
in 1977 \$:									
Scenario 1	849,304	668,975	1,448,709	9,454,472	7,497,866	1,153,825	416,364	471,935	21,961,451
Scenario 2	1,117,368	668,975	1,509,023	9,682,226	7,538,076	1,153,825	428,439	545,652	22,643,684
Scenario 3	1,249,689	668,975	1,538,795	9,794,799	7,557,924	1,153,825	434,400	582,040	22,980,447

TABLE C-6. EQUIPMENT COSTS AND USEFUL LIFE REPORTED BY SELECT VENDORS

Description	Cost	Useful life (years)
Storage & recovery unit	\$ 367,300	20
Waste heat boilers	829,821	20
Kiln	1,336,209	10
Waste collector conveyor	305,674	20
Waste gas fan	149,618	20
Electrostatic precipitator	2,571,500	20

specifically for capital and economic development (approximately \$6 million); and (2) grants obtained from the State of Maryland (\$4 million) and the Federal Government (\$7 million).

Since the interest expense incurred by the City of Baltimore associated with the construction of the plant was minimal, a cost was imputed which would represent total debt financing charges. The latest issuance of debt in the City of Baltimore was in April 1977. The effective yield on the bond was 5.3 percent. Using this most recent interest rate and assuming a 20-year maturity on the bonds, the imputed finance costs for the project are derived in accordance with EPA guidelines (for each of the scenario costs).

The summary capital costs in accordance with EPA's Accounting Format are presented in Table C-7. As indicated there are wide variations in costs per Mg. This is primarily due to projected differences in the operating reliability of the plant (i.e., in Scenario 1 the number of operating days is projected at 104 as opposed to the Scenario 3 estimate of 312 days).

CLASSIFICATION OF COSTS PER EPA'S COST CENTERS

In the Request for Proposal, EPA delineated seven cost centers to which all capital costs should be identified. These cost centers include:

- o Receiving
- o Size reduction
- o Storage and recovery
- o Thermal processing
- o Energy recovery
- o Residue separation
- o General plant

All cost elements identified as General Plant were to be reallocated on a proportional basis according to dollar amount to the remaining six cost

TABLE C-7. PROJECTED SCENARIO CAPITAL COST SUMMARY

Item	Scenario 1	Scenario 2	Scenario 3
Capital cost (\$):			
Land	\$ 849,000	\$ 1,117,000	\$ 1,250,000
Site preparation	669,000	669,000	669,000
Design	1,449,000	1,509,000	1,539,000
Construction	9,454,000	9,682,000	9,795,000
Real equipment, including replacements	7,498,000	7,538,000	7,558,000
Other equipment, including replacements	1,154,000	1,154,000	1,154,000
Contingencies			
Startup and working capital			
Financing and legal	416,000	428,000	434,000
Other costs	472,000	546,000	582,000
Total initial capital investment (\$)	21,961,000	22,643,000	22,981,000
Estimated useful life of facility (years)	14.5	14.5	14.5
Total interest to be paid (\$)	13,684,000	14,109,000	14,319,000
Total capital cost (\$)	35,645,000	36,752,000	37,300,000
Annual capital cost (\$)	2,458,000	2,535,000	2,572,000
Annual throughput (Mg)	67,000	203,000	270,000
Capital cost per Mg (\$)	36.70	12.50	9.50

centers. Once accomplished, the six remaining cost centers would be identified with one of three major systems as follows:

<u>Cost Center</u>	<u>Major System</u>
Receiving Size Reduction Storage and Recovery	Waste Preparation
Thermal Processing Energy Recovery	Energy Recovery
Residue Separation	Residue Separation

Some modification was necessary due to the elimination of the residue separation system and the addition of the electrostatic precipitator. Therefore, summary costs were presented for only five cost centers.

All capital costs identified through the Capital Expenditures Extract as well as additional equipment expenditures, were researched for reclassification by cost center. For the most part, all Capital Expenditures Extract costs, exclusive of those pertaining to the Original Contract and Supplemental Agreement, due to their cost nature (e.g., legal, land acquisition, and site preparation) were classified under General Plant.

A detailed listing of major plant equipment items was prepared from as-built drawings, operation manuals, and Monsanto computer printouts. All costs extracted from the Original Contract and Supplemental Agreement computer printouts were then identified, to the extent possible, with the listing of major equipment items. This was determined through utilization of Monsanto's Original Contract cost coding system which identified costs to specific equipment items. For the Supplemental Agreement, the invoices contained sufficient detail to identify costs with equipment items. Costs not identified with a major equipment item were charged directly to cost centers based on Monsanto's coincident cost center coding. (A more detailed discussion of the classification of costs is presented in Section C-11).

Once costs had been identified with major equipment items, all equipment items were identified with one of the cost centers based on the extent to which an equipment's function corresponded to a cost center's performance characteristics.

Summary cost center distributions are presented in Tables C-8 and C-9. In Table C-8, the impact of the exclusions and additions to the cost center distributions are presented. Table C-9 presents the final capital cost allocation for each of the three scenarios. The conversion of these cost center summaries into subsystem costs results as shown in Table C-10.

NORMALIZATION OF COSTS

In the EPA Accounting Format, guidelines are established for accounting formats to facilitate comparison and analysis of waste recovery systems. Two

TABLE C-8. EXCLUSIONS/ADDITIONS PER EPA COST CENTER

Calibration	Receiving	Size Reduction	Storage and Recovery	Thermal Processing	Energy Recovery	Residue Separation	General Plant	Costs Not Reallocated or Identified	Total
Aggregate Costs Prior to Calibration									
Original Cont.	\$1,339,006	\$1,230,067	\$1,122,659	\$4,400,025	\$1,081,785	\$857,626	\$2,706,362		\$16,742,000
Supp. Agr.	13,756	296,411	92,614	2,628,861	130,542	24,400	417,781		3,801,183
Other Costs	2,905	5,547		2,606	130,485	17,941	1,511,807	\$315,040	1,986,031
Total	1,355,367	1,532,045	1,215,263	7,031,492	3,544,812	899,967	4,638,430	\$315,040	20,332,416
Original Cont. (1,648,649)	1,189,260	1,092,504	997,099	3,907,956	2,738,915	761,714	2,405,903		13,093,131
Supp. Agr. (1,086,317)	1,851	138,346	11,613	279,084	87,941	9,257	171,576		719,868
Other Costs (4,733,166)	2,605	5,547		2,606	130,485	17,941	1,511,807	\$315,040	1,986,031
Total	1,193,716	1,256,397	1,008,712	4,189,646	2,957,341	788,912	4,089,286	\$315,040	15,799,250
Exclusion of Material Recovery System Costs									
Original Cont. (901,258)	1,189,260	1,092,504	997,099	3,907,956	2,738,915		2,405,903		12,192,093
Supp. Agr. (9,257)	1,851	138,346	11,613	279,084	87,941		171,576		710,411
Other Costs (120,703)	2,605	5,547		2,606	130,485		1,409,045	\$315,040	1,865,138
Total	1,193,716	1,256,397	1,008,712	4,189,646	2,957,341		3,846,980	\$315,040	14,071,728
Exclusion of Gas Scrubber System Costs									
Original Cont. (662,545)	1,189,260	1,092,504	997,099	3,265,411	2,738,915		2,405,903		11,529,548
Supp. Agr. (33,761)	1,851	138,346	11,613	265,323	87,941		171,576		676,850
Other Costs	2,605	5,547		2,606	130,485		1,409,045	\$315,040	1,865,138
Total	1,193,716	1,256,397	1,008,712	3,493,340	2,957,341		3,846,980	\$315,040	14,071,728
Inclusion of ESP Costs									
Original Cont.				3,265,411					
Supp. Agr.				265,323					
Other Costs				2,606					
Total	2,571,500	1,256,597	1,008,712	6,084,840	2,957,341		3,846,980	\$315,000	16,643,226
Imputed Landfill Costs									
1st Scenario	300,589			6,365,429					
2nd Scenario	904,336			6,969,176					
3rd Scenario	1,202,356			7,267,159					
Imputed 22 Bond Finance Costs									
1st Scenario	338,876						4,185,856		
2nd Scenario	350,951						4,197,831		
3rd Scenario	356,912						4,203,692		
Aggregate Costs Restated in 1977 Dollars									
1st Scenario	1,622,605	1,652,327	1,368,481	7,584,640	3,980,822		5,351,926	390,650	21,961,451
2nd Scenario	1,622,605	1,662,327	1,368,481	8,254,799	3,980,822		5,364,001	390,650	22,653,030
3rd Scenario	1,622,605	1,662,327	1,368,481	8,535,601	3,980,822		5,369,962	390,650	22,980,448
Final Cost Distributions									
1st Scenario	1,623,000	1,662,000	1,368,000	7,585,000	3,981,000				21,961,000
2nd Scenario	1,623,000	1,662,000	1,368,000	8,255,000	3,981,000				22,653,000
3rd Scenario	1,623,000	1,662,000	1,368,000	8,536,000	3,981,000				22,981,000

TABLE C-9. CAPITAL COSTS PER EPA COST CENTER INCLUDING ADJUSTMENTS*

Cost center	Scenario 1	Scenario 2	Scenario 3
Receiving	\$ 2,197,000	\$ 2,198,000	\$ 2,141,000
Size reduction	2,236,000	2,237,000	2,238,000
Storage and recovery	1,827,000	1,828,000	1,829,000
Thermal processing	10,284,000	11,075,000	11,466,000
Energy recovery	5,417,000	5,305,000	5,307,000
Total	21,961,000	22,643,000	22,981,000

* Dollar amounts for receiving and energy recovery decrease because of the method of allocation. The indirect costs (general plant) are allocated based on each remaining cost center's relative percentage of direct costs. As thermal processing direct costs increase, their subsequent share of the interest costs increases, resulting in decreased costs for receiving and energy recovery.

TABLE C-10. SUBSYSTEM CAPITAL COSTS

Scenario	Waste Preparation	Energy Recovery
1	\$6,260,000	\$15,701,000
2	6,263,000	16,380,000
3	6,208,000	16,773,000

formats are presented, a standardized accounting format, and a normalized accounting format.

The standardized accounting format and its assumptions are designed to reflect the costs and revenues of a system incorporating the site-specific parameters. This gives recognition to varying local conditions such as labor rates, etc.

The normalized accounting format also reflects costs and revenues, but removes the site specific aspects of the parameters affecting plant costs. This enables a comparison to be made of different facilities by examining cost differences due to variances in plant design.

The Accounting Format provides guidelines and instructions for converting costs to a normalized basis. The results of this normalization for the Pyrolysis Plant are presented in Table C-11.

Due to unavailable detailed cost information, only 10 percent of the total capital costs could be normalized. Cost components which could not be normalized include construction, real equipment, and other equipment. The construction cost could not be adjusted because of lack of information concerning man-hours and overall labor input. Equipment costs could not be adjusted due to the lack of information for segregating freight costs.

TABLE C-11. NORMALIZED SCENARIO CAPITAL COSTS SUMMARY

Item	Scenario 1	Scenario 2	Scenario 3
Land	\$ 250,000	\$ 480,000	\$ 590,000
Site preparation	88,000	168,000	207,000
Design*	1,449,000	1,509,000	1,539,000
Construction*	9,454,000	9,682,000	9,795,000
Real equipment, including replacements*	7,498,000	7,538,000	7,558,000
Other equipment, including replacements*	1,154,000	1,154,000	1,154,000
Contingencies			
Start up and working capital			
Financing and legal	439,000	453,000	460,000
Total initial capital investment, (\$)	20,332,000	20,984,000	21,303,000
Estimated useful life of facility, (years)	14.5	14.5	14.5
Total interest to be paid (\$)	21,484,000	21,141,000	21,463,000
Total capital cost (\$)	41,816,000	42,125,000	42,766,000
Annual capital cost (\$)	2,884,000	2,905,000	2,949,000
Annual throughput (Mg)	67,000	203,000	270,000
Capital cost per Mg (\$/Mg)	43.00	14.30	10.90

* Costs are in 1977 dollars.

SECTION C-4

OPERATING AND MAINTENANCE COSTS

INTRODUCTION

The intent of the scope of work for the Baltimore Evaluation was to set forth the actual costs incurred for operation and maintenance at the Pyrolysis Plant. These expenditures relate to the acquiring of property or benefits that do not extend beyond the current accounting period. Once ascertained, these costs were to be classified according to EPA guidelines set forth in the Accounting Format (Section C-7), distributed to EPA established cost centers, and "normalized" in accordance with EPA's Accounting Format guidelines. However, certain major adjustments to this approach were agreed upon between the contract officer and SYSTECH and are discussed in detail in the following section.

METHODOLOGY

Due to the discontinuous plant operations and the incompatibility of the City accounting records with respect to EPA guidelines, the initial approach of auditing and gathering of historical information was not possible. As an alternative, operating and maintenance costs were projected utilizing engineering and operating specifications provided by SYSTECH.

Parameters and data were provided by SYSTECH for three separate sets of operating conditions. All costs which are ultimately reflected in the EPA classification categories were based on this scenario approach. Table C-12 illustrates the three sets of scenario parameters. In addition, Table C-13 presents unit costs for the pertinent operating and maintenance components. Arthur Young & Company cannot confirm the accuracy of the projected costs included in the forecasts.

As illustrated in Table C-12, the operating status of the plant has been broken into four categories: downtime, heating and cooling of the process area, standby, and normal processing. Each of the scenarios reflect a different level of plant operation.

Scenario 1 is based entirely on actual plant operating history during the nine month period from December 1976 to August 1977. During this period, the plant operated on an average of less than two weeks continuously and was shut down approximately six days between operating runs. This average cycle continued throughout the operating period monitored. Thus, during the course of the year, the plant would be shut down 24 times for a period of 6.5 days per shutdown. Further, each time the plant was shut down, there was an

TABLE C-12. SCENARIO OPERATING PARAMETERS*

	Scenario 1:	Scenario 2:	Scenario 3
Operating schedule:	24 hr/day, 6 days/week, 24 shutdowns/yr	24 hr/day, 7 days/week, 8 shutdowns/yr	24 hr/day, 7 days/week, 4 shutdowns/yr
Operating status (days):			
Normal processing, †	104	264	312
Standby, §	56	21	18
Heating and cooling, ¶	48	16	8
Downtime, **	157	64	27
Refuse feed rate:			
Mg/hr	27	32	36
Mg/yr	67,000	203,000	270,000
Steam production (kg/hr):			
Normal processing	50,000 (2/3) 35,000 (1/3)	59,000 (2/3) 35,000 (1/3)	66,000 ---
Standby	35,000	35,000	35,000
Staffing:			
Plant manager	1	1	1
Plant supervisor	1	1	1
Clerk typist	1	1	1
Chief operators	5	4	4
Field operators	5	12	8
Ram operators	3	--	--
Equipment operators	3	4	4
Laborers	5	7	5
Scalemen	1	1	1
Engineers	--	1	1
Laborers/chauffeurs	7	5	4
Maintenance supervisor	1	1	1
Electricians	2	2	1
Mechanics	3	6	4
Welders	2	1	1
Oilers	--	1	1
Instrument technicians	--	1	1
Total staffing	40	49	39
Fuel consumption (ℓ/hr):			
No. 2 fuel:			
Normal processing	660	660	660
Standby	3,260	3,260	3,260
Heating and cooling	1,960	1,960	1,960
Downtime	0	0	0

CONTINUED

TABLE C-12. CONTINUED

	Scenario 1:	Scenario 2:	Scenario 3:
Casoline:			
Normal processing	620	620	620
Standby	620	620	620
Heating and cooling	93	93	93
Downtime	93	93	93
Diesel fuel:			
Normal processing	208	208	208
Standby	208	208	208
Heating and cooling	64	64	64
Downtime	64	64	64
Electricity consumption (kw):			
Normal processing	2,100	2,100	2,100
Standby	1,109	1,109	1,109
Heating and cooling	1,109	1,109	1,109
Downtime	142	142	142
Water consumption (ℓ/day):			
Normal processing	1,595,380	1,835,140	2,021,620
Standby, ††	1,195,780	1,195,780	1,195,780
Heating and cooling	187,780	187,780	187,780
Downtime	187,780	187,780	187,780
Sewer flow (ℓ/day):			
Normal processing	395,380	419,140	437,620
Standby	355,780	355,780	355,780
Heating and cooling	187,780	187,780	187,780
Downtime	187,780	187,780	187,780

* Provided by SYSTECH.

† Constitutes processing of waste.

§ Constitutes onstream with no processing of waste.

¶ Involves startup and cool-down of kiln.

** No activity, plant shut down.

†† 35 Mg/hr of steam.

TABLE C-13. OPERATING AND MAINTENANCE UNIT COST DATA*

Item	Amount
Salary rates (annual, FY 77-78):	
Plant manager	\$24,250
Plant supervisor	20,061
Clerk typist	7,572
Chief operators	16,277
Field operators	14,765
Ram operators	14,765
Equipment operators	9,518
Laborers	8,570
Scalemen	7,313
Engineers	17,326
Laborers/chauffeurs	8,216
Maintenance supervisor	17,327
Electricians	10,360
Mechanics	12,728
Welders	10,742
Oilers	8,216
Instrument technicians	17,450
Employee benefits rate (% of salary costs):	16.74
Fuel rates:	
No. 2 fuel oil	\$0.083/ℓ
Gasoline	0.095/ℓ
Diesel fuel	0.092/ℓ
Electricity rate	\$0.03/kwh
Water and sewer rates (quarterly basis):	
First 141,500 ℓ consumed	\$0.127/1,000 liters
Next 1,275,000 ℓ consumed	0.079/1,000 liters
Any additional water consumed	0.053/1,000 liters
Chemical costs:	
Sulfite	\$0.616/kg
Chelate	1.210/kg

* All cost information obtained between 5/77 and 7/77.

accompanying one day period for cooling the system prior to the downtime and a one day period for heating the system in preparation for operation. Therefore, the 24 shutdowns led to 48 days of plant unavailability. During the demonstration, it was decided to halt the processing of waste on Sunday to allow the staff to perform necessary maintenance functions. Process temperatures were maintained by firing additional fuel oil. This scheduled standby time accounted for another 23 days per year of plant unavailability. Emergency maintenance or process deviations (upsets) accounted for an additional day and one half of standby per operating week, or a yearly total of 33 days of additional standby. Thus, on a yearly basis, the plant is available for a total of 104 days of onstream time (365 days less 157 days of downtime, 48 days of heating and cooling, and 56 days of standby).

The operating status changes in Scenario 2 were based on an extension of the existing plant operation with an expanded operating staff and more efficient administrative procedures. It appears likely that the above changes in plant operation can increase the average continuous plant operating period to slightly over a month. If this is assumed, the number of maintenance downtimes would approximate eight per year. If the number of downtimes are reduced, most likely the duration of each will increase. Therefore, it is assumed each duration will average eight days, yielding a total downtime of 64 days. Heating and cooling periods remain at two days per downtime, yielding a total of 16 days for heating and cooling. Standby time on Sunday could be eliminated by expanding the staff to the proper size. The final assumption made for this scenario is that standby time for maintenance and operational emergencies can be reduced to 21 days, 7 percent of the remaining available time (295 days). As a result, the total available operating time is 264 days (365 days less 64 days downtime, 16 days heating and cooling, and 21 days standby).

The assumptions made for Scenario 3 are based on the most optimistic operating conditions likely to occur, given the projected equipment improvements presently being initiated. This scenario assumes an increase in labor productivity and a market for all of the steam produced. This scenario's operating status provides for quarterly, one-week maintenance shutdowns, accounting for 27 days of downtime. The heating and cooling periods are again two days each, accounting for an additional eight days of downtime. It is assumed that annual emergency standby time can be reduced to 18 days under optimal conditions. These assumptions provide for a total available operating time of 312 days (365 days less 27 days of downtime, eight days of heating and cooling time, and 18 days of emergency standby). This estimate closely corresponds with Monsanto's original projections on the plant level of operation but was determined on an independent basis.

Other major differences in scenario parameters include variations in feed rate, steam production, and staffing. Except for the staffing estimates, the scenario parameters are based on SYSTECH and City data findings. The staffing estimates (for the second and third scenarios) are based on SYSTECH engineering judgement.

Since the kiln is directly fed from the shredder, the kiln feed rate was determined from shredder throughput. The average shredding rate according to City records is 27 Mg/hr (30 tph) and the maximum rate is 36 Mg/hr (40 tph). The feed rate for Scenario 1 was therefore established at 27 Mg/hr (30 tph); the Scenario 3 feed rate was established at 36 Mg/hr (40 tph) (optimal conditions). The value for Scenario 2 was established at 32 Mg/hr (35 tph) or approximately the average of the other two scenarios.

The steam production rate for each of the three scenarios was determined by calculating the average hourly steam production (from the City data sheets) over a two-day period and assuming the feed rate averaged 27 Mg/hr (30 tph). This yields a steam production rate of 50 Mg/hr (110,250 lb/hr.) for the first scenario. Based on a straight line projection of 1.85 Mg (steam)/Mg(refuse) the steam production rates for the second and third scenario are 59.2 Mg/hr (130,540 lb/hr) and 66 Mg/hr (145,500 lb/hr), respectively.

CLASSIFICATION OF COSTS PER EPA ACCOUNTING FORMAT

The following sections discuss in general the methodology applicable to each EPA cost classification.

Salaries

In accordance with the EPA guidelines, salaries were distinguished as to general and administrative, operating, and maintenance. Salary costs were then projected for each scenario using the parameters presented in Table C-13. Salary rates used in computing projected costs were obtained from the City of Baltimore fiscal year 77-78 budget for the Landgard Plant and through discussions with plant management. Where salary ranges were presented for positions, the midpoint of the range was used for cost determination. The total salaries presented for each scenario are exclusive of laborer/chauffeur personnel costs. In accordance with the EPA guidelines, these specific personnel costs are included in total residue revenue costs. Table C-14 illustrates salary costs for each of the three scenarios.

Employee Benefits

Employee benefits costs were determined by reference to the City of Baltimore Landgard budget for fiscal year 77-78. A salary benefit factor was determined by relating projected benefit costs to projected salary costs. Employee benefits include the employer's share of FICA, contributions to the employee's retirement system, share of medical and health insurance, workman's compensation, and health and welfare fund. The 16.74 percent factor calculated was then applied to total scenario salary costs to arrive at Table C-15.

TABLE C-14. ANNUAL SALARIES (FY 1977-78)

Position	Scenario Manloadings			Average Annual Salary	Scenario Salary Costs		
	1	2	3		1	2	3
General and Administrative:							
Plant Manager	1	1	1	\$24,250	\$ 24,250	\$ 24,250	\$ 24,250
Plant Supervisor	1	1	1	20,061	20,061	20,061	20,061
Clerk/Typist	1	1	1	7,572	7,572	7,572	7,572
Subtotal					51,883	51,883	51,883
Operations:							
Chief Operator	5	4	4	16,277	81,385	65,108	65,108
Field Operator	5	12	8	14,765	73,825	177,180	118,120
Ram Operator	3			14,765	44,295		
Equipment Operator	3	4	4	9,518	28,554	38,072	38,072
Laborer	5	7	5	8,570	42,850	59,990	42,850
Scalemen	1	1	1	7,313	7,313	7,313	7,313
Engineer		1/2	1/2	17,326		8,663	8,663
Subtotal					278,222	356,326	280,126
Maintenance:							
Maintenance Supervisor	1	1	1	17,327	17,327	17,327	17,327
Electricians	2	2	1	10,360	20,720	20,720	10,360
Mechanics	3	6	4	12,728	38,184	76,368	50,912
Welders	2	1	1	10,742	21,484	10,742	10,742
Oilers		1	1	8,216		8,216	8,216
Instrument Technician		1	1	17,450		19,195*	19,195
Engineer (50 %)		1/2	1/2	17,328		8,664	8,664
Subtotal					97,715	161,232	125,416
Total					427,820	569,441	457,425

* Include 10 percent premium.

TABLE 3-15. TOTAL SCENARIO SALARY COSTS

Scenario	Total Salary	Benefit Cost
1	\$427,820	\$71,617
2	569,441	95,324
3	457,425	76,573

Fuel

In the processing of solid waste, fuel oil, gasoline, and diesel fuel costs are incurred. Number 2 fuel oil is consumed by the kiln and gas purifier burners in the thermal processing of the solid waste. Gasoline and diesel fuel expenses are incurred through the transport of waste residue to and from the landfill disposal site and for internal vehicle operations (i.e., city cars, bobcats, forklift trucks, dozers, cranes, and front end loaders).

Annual costs for Number 2 fuel oil were computed by applying the unit cost of fuel to the amount of fuel consumed under each plant operating mode (i.e., standby, normal processing, heating and cooling, and downtime) and the projected number of days per plant operating mode. The Number 2 fuel oil consumption data was provided by SYSTECH and based on their monitoring of the different plant operating modes (Table C-12). Unit costs for fuel were based on information obtained from the City of Baltimore.

For gasoline and diesel fuel, costs were computed in a similar manner from field measurements. The unit costs of gasoline and diesel fuel were applied to the amount of fuel consumed under each operating mode and to the projected number of days per plant operating mode.

The computed fuel costs for each of the three scenarios are shown in Table C-16.

TABLE C-16. SCENARIO FUEL COSTS

	Scenario 1	Scenario 2	Scenario 3
#2 Fuel oil	\$687,798	\$545,927	\$558,319
Diesel fuel	4,269	5,925	6,521
Gasoline	11,235	17,493	19,746
Total	\$703,302	\$569,345	\$584,586

Electric Costs

Plant electrical costs are incurred from general utility costs such as heating, lighting, and air conditioning, and from the operation of plant equipment items. Plant equipment items which require electricity include all motors for the pumps, conveyors, fans, and shredders.

Electrical costs were computed based on their unit cost and the amount consumed. The amount consumed is a function of the operating status of the plant. For example, during downtime, all motors are off, resulting in reduced electrical costs. During standby, heatup, and cool down, many of the subsystems are inoperative (e.g., ram feeders, shredders, etc.) and the plant electrical consumption is likewise reduced.

Projected electrical costs were based on Baltimore Gas and Electrical Company (BG&E) recorded demand readings during the varying plant operating modes. The rates per kilowatt hour used in the cost projections were also determined through contact with BG&E.

Adjustments to the measured electrical demand data were made to account for the inclusion of an electrostatic precipitator (ESP) and the exclusion of the residue separation and gas scrubber systems. Using electrical demand data for the residue separation and gas scrubber systems as provided by SYSTECH (100 kw) and estimated electrical demand for the ESP (500 kw) as provided by a product manufacturer, the estimated electrical demand is shown in Table C-17.

TABLE C-17. ESTIMATED ELECTRICAL DEMAND

	Measured	Adjusted
Normal processing	1800	2200
Standby	1100	1500
Heating and cooling	1100	1500
Downtime	140	140

This resulted in the following annual electrical costs for each of the three scenarios:

Scenario 1:	\$293,248
Scenario 2:	\$463,024
Scenario 3:	\$523,131

Water and Sewer Costs

Plant water and sewer costs are primarily attributed to: (1) boiler water consumption for the generation of steam and (2) water cooling, which is necessary for the operation of the kiln, shredders, gas purifier, and main fan. The bulk of the water is used in the boilers for the production of steam.

Sewer and water costs were computed by applying the City water and sewer rate structures to the amount of water consumed and sewage discharged under each plant operating mode. Quantities of water consumed and sewage discharged were monitored by SYSTECH for the varying operating modes. Rates used in the cost computations were derived from the City of Baltimore rate structure. As of October 2, 1977, City agencies will be billed for water and sewer services. Below are current estimated water and sewer charges for each of the three scenarios.

Scenario 1:	\$20,000
Scenario 2:	\$35,100
Scenario 3:	\$43,100

Maintenance

This category has been modified from the EPA standard format to include both replacement and maintenance costs. Rather than listing replacement costs as a separate item as indicated by the EPA guidelines, it is assumed that any replacements included here represent minor equipment costs charged to expense, thereby making these costs synonymous with maintenance and repair. Replacement of any major equipment item which would be of any monetary consequence, is assumed to be capitalized in an appropriate asset account. For example, the cost of replacement and repair work for the kiln was included in the Supplemental Agreement. All costs contained in the Supplemental Agreement were categorized as capital costs and are identified in the Capital Expenditures Extract.

Due to continuing equipment modifications and the erratic operating status of the plant, it was not practical to utilize the City's recording the maintenance and repair costs. From an accounting perspective, since the plant has not been properly operating and plant modifications are persisting, maintenance costs recorded during this period are not a good measure of costs. As a result, our approach involved reference to the Internal Revenue Service guidelines for maintenance and repairs for solid waste disposal plants as set forth in Revenue Procedure 72-10. This approach necessitates computing maintenance costs by application of the recommended IRS guideline percentage to the total depreciable capital asset base. The rate for solid waste disposal plants is 5.5 percent.

Using the annual IRS guideline repair and maintenance allowance, projected costs for each of the three scenarios are shown in Table C-18.

TABLE C-18. PROJECTED MAINTENANCE COSTS

	Depreciable Capital Asset Base*	Annual Maintenance Expenses
Scenario 1	\$20,696,000	\$1,138,000
Scenario 2	\$21,098,000	\$1,160,000
Scenario 3	\$21,297,000	\$1,171,000

*The depreciable capital asset base for each of the three scenarios was derived from deducting Land and Finance and Legal classification costs from scenario aggregate capital costs.

The annual repair and maintenance allowance includes the cost of labor. Since EPA requests that the cost of maintenance personnel be listed separately, the in-house labor costs have been deducted, resulting in the following revised repair and maintenance allowance costs:

Scenario 1:	\$1,024,000
Scenario 2:	\$ 972,000
Scenario 3:	\$1,025,000

Chemical Costs

Even though not part of the EPA format cost classifications, the cost of chemicals is a significant element in annual operating costs and, accordingly, should be listed separately in the analysis.

The major chemical expenses are attributed to chelate and sulfite, which treat and control the water entering the boilers for the production of steam.

Chelate and sulfite costs were determined by application of their unit costs to the amounts consumed per ton of waste processed. Quantities consumed were provided by SYSTECH, whereas unit costs were derived from vendor price lists. The following are estimated chemical costs for each of the three scenarios:

Scenario 1:	\$ 3,000
Scenario 2:	\$ 8,000
Scenario 3:	\$11,000

Landfill Costs

The cost of disposing of plant residue consists of the expenses of hauling the residue to the landfill and the cost of disposal at the landfill site. Hauling expenses primarily include fuel costs and direct labor costs. Costs incurred at the landfill site include labor and material expenses.

The expenses incurred at the landfill site were computed based on the landfill presently utilized for residue disposal, the Pennington Avenue landfill. With an estimated operating budget for the landfill of \$167,000 for the fiscal year 76-77, the cost of residue was based on the portion of residue attributed to the Pyrolysis Plant.

As reported by the Department of Public Works, the Pennington Avenue landfill, which receives all residue from the plant, has a capacity of 1,644,000 m³ (2,150,000 yd³). With an estimated useful life of three years, the annual operating and maintenance cost approximates 31¢ m³. By applying this amount to the number of cubic meters of residue which would be transferred from the Pyrolysis Plant to the landfill site, costs can be derived. SYSTECH, using extrapolated field data, determined the number of cubic meters from the amount of refuse processed for each scenario (Table C-12), the residue output as a percentage of residue processed and residue bulk density (Volume II, Section 3). Under each of the three scenarios, projected annual expenses incurred are as follows:

Scenario 1:	\$ 6,000
Scenario 2:	\$18,000
Scenario 3:	\$24,000

The labor cost attributed to the hauling of the residue to the landfill is based on the number of laborers/chauffeurs delineated in each of the scenarios (Table C-12). With a budgeted salary of \$9,591 per laborer/chauffeur for fiscal year 77-78, this yields the following:

Scenario 1:	\$67,140
Scenario 2:	\$47,957
Scenario 3:	\$38,365

Scenarios 2 and 3 costs are less due to assumed more efficient loading techniques.

The last component of landfill costs involves the determination of fuel costs associated with the transport of the residue to the disposal site. Fuel costs were computed on the basis of the number of annual trips required under each of the scenarios. Assuming that the average load per trip approximates 18 metric tons (20 tons), the number of trips required under each scenario is as follows:

Scenario 1:	1,722 trips
Scenario 2:	5,181 trips
Scenario 3:	6,889 trips

Since each trip to and from the landfill covers a distance of approximately 30 miles, the fuel cost per trip was estimated at \$2.10 (22.7 liters/48.4 km $\times$ 9.4¢/liter).

To avoid duplication of costs, the fuel costs derived in this section are deducted from the gasoline costs presented under "Fuel Cost", in the summary operating and maintenance expense exhibits.

In summary, the cost of residue disposal for each of the scenarios is shown in Table C-19.

TABLE C-19. ANNUAL RESIDUE DISPOSAL COSTS

Cost	Scenario 1	Scenario 2	Scenario 3
Site	\$ 6,000	\$18,000	\$24,000
Labor*	67,140	47,957	38,365
Fuel	3,616	10,880	14,467
Total	\$76,756	\$76,837	\$72,832

*Includes 16.74 Fringe Benefit allowance.

Other Overhead Costs

The City of Baltimore allocates indirect costs to operating departments annually, in accordance with EPA requirements. Financial Management Circular 74-4, "Cost Principles Applicable to Grants and Contracts with State and Local Governments," is adhered to in allocating the City's indirect costs and overhead to the operating departments. However, there is no allocation of costs beyond the operating departments (e.g., Department of Public Works). To compute indirect costs related to the Pyrolysis Plant overhead, administrative costs were allocated in the following manner:

- o Department of Public Works to Bureau of Operations
- o Bureau of Operation to Sanitation and Waste Removal
- o Sanitation and Waste Removal to Disposal
- o Disposal to Pyrolysis Plant

All allocations were made on a pro rated basis. Each subdivision of a department received an overhead expense based on its proportional share of total department budgeted expenditures. For example, the Department of Public Works' overhead expense was \$3,062,630. The Bureau of Operations' (a division of Public Works) budget was 64 percent of the total budget. Therefore, the

indirect cost allocable to the Bureau of Operations was \$1,960,083. Further allocations result in \$70,840 of indirect and Department overhead costs allocable to the Pyrolysis Plant (Table C-20).

Other costs included under "Overhead Costs" are illustrated in Table C-21. During the analysis and determination of costs associated with the Landgard project, costs were found to exist that were not specifically mentioned in the EPA operating and maintenance cost guidelines. These costs are essentially of a fixed nature in that they specifically relate to general facility operations, irrespective of the level of plant activity. The amounts were taken from the plant's 1976-1977 budget and should remain relatively constant regardless of the scenario application. As a result, total annual "Other Overhead" costs total \$195,840 for each of the scenarios.

Table C-22 summarizes operating and maintenance expenses per EPA classification for each of the three scenarios. Table C-23 summarizes operating and maintenance expenses per Mg of refuse processed.

NONAPPLICABLE OPERATING AND MAINTENANCE COSTS

Certain costs normally associated with commercial enterprise are not always incurred in a municipally run plant facility. Whereas a private concern would be required to pay assorted taxes and license fees, the Baltimore Landgard facility is exempt from such charges. Furthermore, under normal circumstances, private businesses incur financial expenses associated with management fees, legal fees, and other professional services. Where the City provides these types of services to the plant, such services are not chargeable directly to the Landgard budget but rather are passed on through the Department of Public Works to the plant, on a proportional basis, as general overhead expense (Table C-20). Insurance costs are handled similarly. As a result, no costs are found under the EPA Classifications' Taxes and Licenses, Insurance, Management Fees, and Professional Services.

CLASSIFICATION OF COSTS TO COST CENTERS

Computed Scenario 1 operation and maintenance costs were allocated to the seven EPA established cost centers (Table C-24). The basis used in the allocation process for each of the expenses is described as follows:

Salaries and Employee Benefits

Due to the unavailability of manpower allocation data, salaries, and employee benefit costs were apportioned, based on the plant superintendent's estimates. A few personnel costs were directly assigned to cost centers. All other personnel costs were evenly distributed to each of the cost centers.

TABLE C-20. INDIRECT CITY COST ALLOCATION

	Department of Public Works	Bureau of Operations	Sanitation & Waste Removal	Disposal	Pyrolysis
Indirect Costs					
To Public Works*	\$2,663,542				
Public Works Administration	399,088				
Overhead	3,062,630				
To Bureau of Operations		\$1,960,083			
To Sanitation & Waste Removal			\$646,827		
To Disposal				\$135,834	
Disposal Administrative Overhead				126,538	
				262,372	
To Pyrolysis					\$70,840

* This represents the redistribution of costs incurred by Public Building Management, Law, Audits, Data Processing, Treasurer, Real Estate, Civil Service, Accounting Operation, Purchases, Budgets, Payroll Retirement Systems, and Insurance for services rendered to the Department of Public Works for Fiscal Year ended June 30, 1976.

TABLE C-21. OTHER OVERHEAD COSTS

Municipal Telephone Exchange	\$ 4,000
Laundry and Cleaning	5,000
Rental of Operating Equipment	2,000
Rental of Motor Equipment	100,000
Other Miscellaneous	3,000
Motor Vehicle Funds and Lubricants	2,000
Office Supplies	2,000
Clothing and Footwear	1,000
Business Machine Supplies	200
Custodial Materials	200
Control and Recording Supplies	2,000
Indirect Costs	70,840
Total Costs	195,840

TABLE C-22. PROJECTED ANNUAL OPERATING AND MAINTENANCE COSTS*

Item	Scenario 1	Scenario 2	Scenario 3
Salaries†	\$ 428,000	\$ 569,000	\$ 457,000
Employee Benefits†	72,000	95,000	77,000
Fuel‡	700,000	558,000	570,000
Electricity	293,000	463,000	523,000
Water and sewer	20,000	35,000	43,000
Maintenance	1,024,000	972,000	1,025,000
Chemicals	3,000	8,000	11,000
Residue removal	77,000	77,000	77,000
Other overhead	196,000	196,000	196,000
Total annual operation and maintenance costs	2,813,000	2,973,000	2,979,000
Operating and maintenance costs/Mg	\$42.00	\$14.60	\$11.00

* 1977 dollars.

† Excludes those salary and benefit costs applicable to residue removal.

‡ Excludes input fuel costs applicable to residue removal.

TABLE C-23. PROJECTED ANNUAL OPERATING AND MAINTENANCE COSTS
PER Mg OF REFUSE PROCESSED

Item	Scenario 1	Scenario 2	Scenario 3
Salaries	\$ 6.39	\$ 2.80	\$ 1.69
Employee benefits	1.07	0.47	0.29
Fuel	10.46	2.75	2.11
Electricity	4.38	2.28	1.93
Water and sewer	0.30	0.17	0.16
Maintenance	15.28	4.79	3.80
Chemicals	0.04	0.04	0.04
Residue removal	1.15	0.38	0.29
Other overhead	2.93	0.97	0.73
Total cost	42.00	14.65*	11.04*

* These estimates differ from those in Table C-22 due to roundoff.

TABLE C-24. OPERATING AND MAINTENANCE COSTS PER COST CENTER (SCENARIO 1)

Cost classification:	Total cost	Receiving	Size reduction	Storage and recovery	Thermal processing	Energy recovery	General plant
Salaries	\$ 428,000	\$ 22,000	\$ 14,000	--	\$ 44,000	--	\$348,000
Employee benefits	72,000	4,000	2,000	--	7,000	--	59,000
Fuel	700,000	--	--	--	686,000	--	12,000
Electricity	293,000	5,000	34,000	\$ 5,000	215,000	\$ 10,000	24,000
Water and sewer	20,000	--	4,000	--	6,000	10,000	--
Maintenance	1,024,000	102,000	105,000	85,000	479,000	253,000	--
Chemicals	3,000	--	--	--	--	3,000	--
Residue removal	77,000	--	--	--	77,000	--	--
Other overhead	196,000	--	--	--	--	--	196,000
Total	2,813,000	133,000	159,000	90,000	1,516,000	276,000	639,000
General plant allocations:							
Salaries*		69,600	69,600	69,600	69,600	69,600	--
Remaining costs†		17,800	21,200	11,900	203,100	37,000	--
Total		87,400	90,800	81,500	272,700	106,600	--
Grand total	2,813,000	220,000	250,000	171,000	1,789,000	383,000	--

* Salaries were distributed equally to all cost centers.

† The remaining general plant costs were allocated on a pro rata basis.

Fuel Costs

Number 2 fuel oil expenses are allocated to thermal processing. All other expenses are allocated to the general plant.

Electrical Costs

Electrical consumption data were recorded by SYSTECH for each of the major pieces of equipment or breaker box which were in turn assigned to a cost center or module.

Water and Sewer Costs

Water and sewer costs were apportioned to energy recovery and to the general plant. Water and sewer costs incurred during normal processing, heating and cooling, and standby, less the general plant fixed costs, were allocated to energy recovery.

Maintenance

All maintenance costs were allocated on a proportional basis according to the capital assets associated with each cost center, consistent with the overall maintenance cost determination.

Chemicals

All chemical costs were allocated to energy recovery.

Residue Disposal

Residue disposal costs were included in thermal processing.

Other Overhead Costs

Other overhead costs were allocated to the general plant.

The general plant cost center was then allocated to the remaining cost centers on a proportional basis according to cost center capital cost amounts. This then yields a cost of \$641,000 for the waste preparation system and \$2,172,000 for the energy recovery system.

FIXED AND VARIABLE COSTS

Some costs incurred bear a direct relationship to operational levels as well as general and administrative concentration, making it necessary to differentiate between the nature of costs. By defining costs as either fixed or variable, it is possible to project what costs will be at different levels of plant activity. Fixed costs are conventionally defined as costs that do not vary over a relevant range of production. That is, if the plant facility were not in operation, there are certain costs that would continue

to occur. Examples of fixed costs are costs associated with maintaining an office or headquarters, insurance on the plant facility, interest on debt service (if any), plant security, etc. Variable costs encompass those elements of cost that change or fluctuate proportionally with different levels of processing. Examples of variable costs are fuel, chemicals, water, electricity, maintenance, etc. Note, however, that certain portions of variable costs do have elements of fixed costs as well (some water, fuel, and electricity will be required to service an office or headquarters when the plant is operating or shut down).

Since the analysis of historical operating and maintenance expenses relating to Landgard was limited by discontinuous operations, a classification of historical costs into fixed and variable categories was not possible. However, a cost breakdown was made to analyze the nature of all operating and maintenance costs, based on projected scenario costs. Table C-25 illustrates the results. This analysis at a minimum, provides some insight into plant costs when the facility is processing waste in comparison to being down.

NNORMALIZATION OF COSTS

Operating and maintenance costs were normalized in accordance with EPA guidelines using Scenario 1 parameters only. Section 7 illustrates EPA's Accounting Format normalization guidelines.

Normalized operating and maintenance costs are displayed in Table C-26.

TABLE C-25. FIXED VS. VARIABLE OPERATING AND MAINTENANCE COSTS

Item	Fixed	Variable		
		Scenario 1	Scenario 2	Scenario 3
Salaries	\$ 52,000	\$ 376,000	\$ 517,000	\$ 405,000
Employee benefits	9,000	63,000	86,000	68,000
Fuel	5,000	695,000	553,000	565,000
Electricity	37,000	330,000	426,000	486,000
Water & Sewer	8,000	12,000	27,000	35,000
Maintenance		1,024,000	972,000	1,025,000
Chemicals		3,000	8,000	11,000
Residue removal		77,000	77,000	77,000
Other overhead	196,000			
Total Costs	307,000	2,580,000	2,666,000	2,672,000

TABLE C-26. NORMALIZED ANNUAL OPERATING AND MAINTENANCE COSTS

Item	Scenario 1	Scenario 2	Scenario 3
Salaries*	\$ 512,000	\$ 682,000	\$ 543,000
Employee benefits†			
Fuel	670,000	549,000	565,000
Electricity	293,000	463,000	523,000
Water and sewer	49,000	87,000	107,000
Maintenance§	1,024,000	972,000	1,025,000
Chemicals§	3,000	8,000	11,000
Residue removal	124,000	411,000	547,000
Other overhead§	196,000	196,000	196,000
Taxes and licenses¶			
Insurance**			
Management fees**			
Professional services**			
Total costs	2,871,000	3,368,000	3,517,000
Cost per Mg	42.80	16.60	13.00

* Exclude laborer/chauffeur salary costs for landfill disposal.

† Included in salaries.

§ In 1977 dollars.

¶ Not applicable to municipally operated plant.

** Included in "Other Overhead".

SECTION C-5

REVENUES

METHOD OF ACCOUNTING FOR REVENUES

As discussed in "Description of City Accounting System", the City of Baltimore maintains separate accounts for the recording of revenues from sales of ferrous metals, nonferrous metals, and steam produced by the Pyrolysis Plant. However, because steam is the only product being sold, a complete economic analysis of revenues could not be performed. Accordingly, the scenario approach is followed for projected steam revenues only.

COMPILATION AND ALLOCATION OF REVENUE

The City of Baltimore entered into a contract with the Baltimore Gas & Electric Company for the sale of steam generated by the plant. The contract provides the City with a market for the steam thereby avoiding any significant supply and demand problems. The contract provided for a variable price for the steam based upon the fluctuating price of Number 6 crude oil. Using the contract formula, the latest available price for steam approximates \$6.88 per 1,000 kg (\$3.13 per 1,000 lbs.) of steam. When this is applied to the individual scenario parameters, the following revenues are derived:

<u>Scenario</u>	<u>Steam Revenues</u>
1	\$ 978,432
2	\$2,176,612
3	\$3,435,494

Scenario 3 assumes a market is found for all of the steam produced, accounting for a major increase in revenues received.

NORMALIZATION OF STEAM REVENUES

Steam revenues were then normalized according to EPA guidelines. The guidelines call for using a price of \$3.31 per 1,000 kg (\$1.50 per 1,000 lb) of steam. This results in the following revenues for each of the scenarios:

<u>Scenario</u>	<u>Steam Revenues</u>
1	\$ 470,400
2	\$1,046,448
3	\$1,651,680

SECTION C-6

NET OPERATING COSTS

The net operating costs for each of the three scenarios were computed by deriving total costs and revenues. The scenarios' actual and normalized costs were transferred from the pertinent exhibits yielding total costs. Revenues per metric ton were derived by dividing the revenues under each scenario by annual throughputs. The net operating costs are presented in Table C-27 and the normalized net operating cost are presented in Table C-28.

TABLE C-27. PROJECTED COST SUMMARY*

Cost category	Scenario 1 [†]		Scenario 2 [§]		Scenario 3 [¶]	
	(\$/Mg)	(\$/ton)	(\$/Mg)	(\$/ton)	(\$/Mg)	(\$/ton)
Capital costs	\$22.60	\$20.50	\$ 7.70	\$ 7.00	\$ 5.90	\$ 5.30
Interest	14.10	12.80	4.80	4.30	3.60	3.30
Operating and maintenance costs	42.00	38.10	14.60	13.30	11.00	10.00
Total costs	78.70	71.40	27.10	24.60	20.50	18.60
Revenues	14.60	13.20	10.70	9.70	12.70	11.50
Net cost	64.10	58.20	16.40	14.90	7.80	7.10

* In 1977 dollars.

[†] Annual throughput is 67,000 Mg/year (74,000 tons/year).

[§] Annual throughput is 203,000 Mg/year (223,000 tons/year).

[¶] Annual throughput is 207,000 Mg/year (300,000 tons/year).

TABLE C-28. NORMALIZED COST SUMMARY*

Category	Scenario 1†		Scenario 2§		Scenario 3¶	
	(\$/Mg)	(\$/ton)	(\$/Mg)	(\$/ton)	(\$/Mg)	(\$/ton)
Capital costs	20.90	23.00	7.10	7.80	5.40	6.00
Interest	22.10	24.40	7.20	7.90	5.50	6.10
Operating and maintenance costs	42.80	47.20	16.60	18.30	13.00	14.30
Total cost	85.80	94.60	30.90	34.00	23.90	26.40
Revenues	7.00	7.70	5.20	5.70	6.10	6.70
Net operating cost/profit	78.80	86.90	25.70	28.30	17.80	19.70

* In 1977 dollars.

† Annual throughput is 67,000 Mg/yr. (74,000).

§ Annual throughput is 203,000 Mg/yr. (223,000).

¶ Annual throughput is 270,000 Mg/yr. (300,000).

SECTION C-7

RESOURCE RECOVERY PLANT IMPLEMENTATION GUIDES FOR MUNICIPAL OFFICIALS (ACCOUNTING FORMAT)*

The economics of various types of resource recovery systems are difficult to compare. System technologies vary, capital and operating costs vary, revenues from the recovered products vary, the recovered products themselves vary, and the cost accounting methods used to analyze system economics vary. This paper proposed a method of reporting costs and revenues to aid in comparing the costs of various resource recovery systems. The proposed method includes a standardized accounting format and normalized accounting format.

The standardized accounting format facilitates comparison and analysis of resource recovery plant costs and revenues by assuring that all cost and revenue elements are included (or at least that the exclusion of certain items is identified). Whether based on historical or projected data, the standardized accounting format is designed to reflect the costs and revenues of a system, incorporating all site-specific parameters.

The normalized accounting format reflects all costs and revenues for a system, but it is not site specific. General assumptions for certain costs and revenues are used. Normalized accounting information is used to compare systems when site specific information is unavailable or when one wants to compare costs of different systems. The normalized accounting format preserves and highlights the differences resulting from engineering design while eliminating differences resulting from site-specific factors.

The accounting format is presented on the following seven tables. Each item on the tables is explained in the notes following the tables; the numbers in parentheses on the tables match the numbered notes. Those costs that cannot be segregated (e.g., design, construction, real equipment) should be combined and labelled accordingly. (See Tables C-29 through C-35.)

The Office of Solid Waste (OSW) has developed these recommended cost accounting formats as a means of assisting planners, designers, and decision making officials in their resource recovery decisions. Other costs accounting formats available from OSW include collection, incineration,

*Sussman, David B., Resource Recovery Plant Implementation: Guides for Municipal Officials, Accounting Format. SW 157.6, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1976. 17 pp.

sanitary landfill, and shredding. OSW invites users of these formats to forward the data developed along with a designation of their system to OSW so that we will be able to compile data from most of the systems for use by other planners.

TABLE C-29. CAPITAL COSTS - ACTUAL (COSTS IN 19__ \$) (1)

Land	\$ _____	(2)*
Site preparation	_____	(3)
Design	_____	(4)
Construction	_____	(5)
Real equipment, including replacements	_____	(6)
Other equipment, including replacements	_____	(7)
Contingencies	_____	(8)
Start up and working capital	_____	(9)
Financing and legal	_____	(10)
Total initial capital investment	\$ _____	(11)
Estimated useful life of facility (years)	_____	(12)
Total interest to be paid	_____	(13)
Total capital cost	_____	(14)
Average annual capital cost	_____	(15)
Annual throughput (tons)	_____	(16)
Capital cost per ton	\$ _____	(17)

(To Table C-35)

Sources of capital (list):

<u>Source</u>	<u>Amount</u>	<u>Interest rate or return on investment</u>	<u>Period</u>

Total	_____	(18)	

Throughput calculation: (16)

$$\begin{array}{l}
 \frac{\text{_____}}{\text{(Design throughput, daily)}} \times \frac{\text{_____}}{\text{(\% availability)}} \times \\
 \frac{\text{_____}}{\text{(days per week)}} \times 52 \text{ weeks per year} = \frac{\text{_____}}{\text{(tons/year)}}
 \end{array}$$

* Numbers refer to notes.

TABLE C-30. ANNUAL OPERATING AND MAINTENANCE COSTS-ACTUAL (COST IN 19__ \$) (1)

Salaries	\$ _____	(19)
Employee benefits	_____	(20)
Fuel	_____	(21)
Electricity	_____	(22)
Water (and sewer)	_____	(23)
Maintenance	_____	(24)
Replacement equipment	_____	(25)
Residue removal	_____	(26)
Other overhead	_____	(27)
Taxes and licenses	_____	(28)
Insurance	_____	(29)
Management fees	_____	(30)
Professional services	_____	(31)
Total annual operating and maintenance costs	\$ _____	(32)
Operating and maintenance cost per ton	\$ _____	(33)
(To Table C-35)		

TABLE C-31. PRODUCT REVENUES - ACTUAL (REVENUES IN 19__ \$) (1)

Recovered material	Price per ton (34)	Shipping per ton (35)	Ton of material per ton of throughput (36)	Net revenue
Ferrous metal	\$ _____	- _____	x _____	= \$ _____
Glass	_____	- _____	x _____	= _____
Aluminum	_____	- _____	x _____	= _____
Other non-ferrous	_____	- _____	x _____	= _____
Other (list)	_____	- _____	x _____	= _____
Material revenues per throughput ton				\$ _____ (37)
Recovered energy	Price per unit	Shipping per Unit	Units of energy per ton of throughput	Net revenue
_____ (38)	x _____ (39)	- _____ (35)	x _____ (36)	= _____
Energy revenues per throughput ton				\$ _____ (40)
Total revenue per throughput ton				\$ _____ (41)
(To Table C-35)				

TABLE C-32. CAPITAL COST - NORMALIZED (COST IN 1975 \$)

Land	\$ _____	(42)
Site preparation	_____	(43)
Design	_____	(44)
Construction	_____	(45)
Real equipment, including replacements	_____	(46)
Other equipment, including replacements	_____	(47)
Contingencies	_____	(8)
Start up and working capital	_____	(9)
Financing and legal	_____	(48)
Total initial capital investment, "N"	\$ _____	(49)
Estimated useful life of facility (years)	_____	(12)
Total interest to be paid	_____	(50)
Total capital cost	_____	(51)
Annual capital cost	_____	(52)
Annual throughput (tons)	_____	(16)
Capital cost per ton, "N"	\$ _____	(53)
(To Table C-35)		

Sources of capital (list):

<u>Source</u>	<u>Amount</u>	<u>Interest rate</u>	<u>Length of financing period</u>
Municipal bond	_____ (49)	8%	20 years

TABLE C-33. ANNUAL OPERATING AND MAINTENANCE COSTS-NORMALIZED (COST IN 1975 \$)

Salaries	\$ _____	(54)
Employee benefits	_____	(55)
Fuel	_____	(56)
Electricity	_____	(57)
Water (and sewer)	_____	(58)
Maintenance	_____	(59)
Replacement equipment	_____	(25)
Residue removal	_____	(60)
Other overhead	_____	(27)
Taxes and licenses	_____	(61)
Insurance	_____	(62)
Management fees	_____	(63)
Professional services	_____	(64)
Total annual operating and maintenance costs, "N"	\$ _____	(65)
Operating and maintenance cost per ton, "N"	\$ _____	(66)
 (To Table C-35)		

TABLE C-34. PRODUCT REVENUES - NORMALIZED (REVENUE IN 1975 \$)

Recovered material	Price per ton (67)	Shipping per ton (68)	Ton of material per ton of throughput (36)	Net revenue
Ferrous metal	\$ _____	- _____	x _____	= \$ _____
Glass	_____	- _____	x _____	= _____
Aluminum	_____	- _____	x _____	= _____
Other non-ferrous	_____	- _____	x _____	= _____
Other (list)	_____	- _____	x _____	= _____
Material revenues per throughput ton				\$ _____ (69)
Recovered energy	Price per unit	Shipping per unit	Units of energy per ton of throughput	Net revenue
_____ (70)	x _____ (70)	- _____ (71)	x _____ (36)	= _____
Energy revenues per throughput ton				\$ _____ (72)
Total revenue per throughput ton				\$ _____ (73)
(To Table C-35)				

TABLE C-35. SUMMARY (\$ PER THROUGHPUT TON)

	Actual	Normalized
Capital costs	\$ _____ (From Table C-29)	\$ _____ (From Table C-32)
Operating and maintenance costs	\$ _____ (From Table C-30)	\$ _____ (From Table C-33)
Total cost	\$ _____	\$ _____
Revenues	\$ _____ (From Table C-31)	\$ _____ (From Table C-34)
Net operating cost/profit	\$ _____	\$ _____

NOTES

- (1) State what year dollars are used.
- (2) Total cost of land acquired for the resource recovery facility. Include transfer station land if essential part of total system. Include the capital cost of the disposal site that will take the systems residue or is required as disposal backup. This site must be large enough to dispose of all the unrecovered components of the waste stream during the lifetime of the facility. If this disposal site is used for other solid waste disposal, include only that portion chargeable to the resource recovery system.
- (3) Cost of site preparation: Include cost of relocating present tenants, if applicable. Include cost of disposal site preparation.
- (4) A and E or consultant cost for preliminary design, feasibility studies, final designs, checking of shop drawings, inspections during construction, preparation of operating manuals, operator training, and assistance during start-up. Explain what items are covered in this category.
- (5) Construction costs: Include construction management. (Example: buildings, structures, and foundations) do include cost of replacement equipment. See Item 25.
- (6) Real Equipment: Include costs of all real property installed equipment. (Example: processing equipment). See Note 25 for explanation of replacement equipment.
- (7) Other Equipment: Include cost of all ancillary equipment like bulldozers, loaders, office equipment, and trucks that are necessary for plant operation. Include operating spares. Include total cost of any leased equipment, if equipment is leased in lieu of purchase.
- (8) State how much capital is reserved for contingencies.
- (9) State how much capital is reserved for start up and for working capital.
- (10) State cost of bond counsel, legal fees, financial management consultants, etc. Also include interest on capital during construction less anticipated short term return on unspent capital.
- (11) Total initial capital investment. (Sum of Items 2 through 10).
- (12) Designer's estimate; may be longer than financing period, but in no case will it be less.
- (13) Out-of-pocket payments of interest on all debt and fair return (dividends) on equity (stock) when incurred and discounted back to the year in which the data is stated.

- (14) Sum of (11) and (13).
- (15) Item (14) divided by Item (12).
- (16) Cost per throughput ton. To determine the throughput per year take design capacity per day (indicate operating hours per day) times system design reliability or availability (percentage of available capacity) times number of days of planned operation per week times 52 weeks. Example: 1,000 tons per day $\times$.85 (system availability) $\times$ 5 1/2 days per week $\times$ 52 weeks = 243,100 tons per year.
- (17) Item (15) divided by Item (16).
- (18) Must equal Item (11). Include both debt and equity. Interest rate would apply to debt and fair rate of return to equity. Period would be designer's life of facility for equity and length of financing period for debt.
- (19) Total annual salaries. Include all personnel that are necessary for system operation. Include supervisory and administrative personnel. Do not include any collection costs (garbage trucks, etc.). Break down into operating personnel, maintenance personnel, and administrative personnel. If maintenance labor costs are charged to maintenance so state and include in Item (24).
- (20) Includes employer contribution for FICA, health insurance, pensions, etc.
- (21) All system fuel costs. Process, space heat, auxiliary equipment, bulldozers, loaders, etc. (a fuel usage that is charged to the resource recovery system). List by usage and fuel type.
- (22) Total electric bill. Process, office, lighting, heating, auxiliary equipment, air conditioning, etc.
- (23) Include process, cooling, sanitation, lawn care, wash down, boiler feedwater, etc.
- (24) Include all costs, both contractor and in-house. Labor costs may be included in (19). Building maintenance should be segregated from process equipment maintenance.
- (25) Include yearly expenses. Do not include inventory. Include inventory in (7). If parts and supplies are included in maintenance costs, so state. Include in this item funds that are set aside for the replacement of depreciated equipment. State what portion of this item is for parts, supplies, depreciation, and so forth.
- (26) List the cost of disposing of the residue. Include hauling to remote disposal site and cost of disposal. Do not include capital cost of disposal site. On-site handling should be included in Items (11), (6), (7), and (19).

- (27) List other overhead items.
- (28) Include property tax or payment to the City in lieu of taxes, operating licenses, occupancy, and utility taxes, etc.
- (29) Fire, liability, etc.
- (30) Payment to system operator (if applicable).
- (31) Audit fees, legal fees, data processing, etc.
- (32) Total annual operating and maintenance costs. (Sum of Items (19) and (31)).
- (33) Item (32) divided by Item (16).
- (34) List the per ton selling price of the recovered material products. Include information on escalator clauses or specifics, such as a price that is linked to the market price of the material at a specific location. If some recovered products are sold "mixed"; i.e., glass-aluminum fraction, so state and list revenue for whole fraction.
- (35) Freight, handling and demurrage. List the cost of shipping the product to the market. Include any cost that is charged to the system that is associated with the sale of the recovered products. Do not include those items of capital equipment such as trucks or steam lines. This transportation cost may be reflected in the sale price of the recovered item (F.O.B.). If so, state.
- (36) Number of tons of each recovered product per ton of throughput.
- (37) Sum of all material revenues.
- (38) State what form the recovered energy is in (steam, gas, oil, shredded fuel, etc.), and in what unit it is sold (Btu, ton, pound, gallon, etc.).
- (39) List the revenue per unit. Indicate any escalators and state details of how price per unit energy may be linked to a specific market, another fuel, or another energy source.
- (40) Sum of all energy revenues.
- (41) Sum of Items (37) and (40). If applicable, list revenues other than for sale of products; e.g., charge for handling sludge, industrial waste, oversized or bulky waste, or other special waste.
- (42) Calculate minimum number of acres that is necessary for plant as designed. Include disposal site as explained in Item (2). Do not compress, expand, or refit design when calculating minimum acres necessary. Assume \$10,000 per acre.

- (43) Assume 35 percent of (42).
- (44) Design cost should be the same as listed in Item (4).
- (45) Actual construction cost adjusted to national average using standard construction cost data and civil engineering index or other standard indexes.
- (46) &
- (47) All equipment prices should be F.O.B. the supplier. Assume shipping charges are 10 percent of total and add to equipment costs.
- (48) Assume 2 percent of capitalized costs.
- (49) Total initial capital investment, normalized.
- (50) Assume that all capital costs are financed with a 20 year municipal bond at 8 percent interest. Include in Item (50) the total interest paid over a 20-year period.
- (51) Sum of (49) and (50).
- (52) Item (51) divided by Item (12).
- (53) Item (52) divided by Item (16).
- (54) Take the total number of workers that are necessary to run the plant. This should be the same as Item (19). If not, explain. Multiply this number by \$15,500 yearly salary. This cost includes employee benefits.
- (55) Included in (54).
- (56) List fuel use as in Item (21). Assume \$.60 per gallon for gasoline; \$.40 per gallon for diesel fuel; \$2.00 per million Btu for natural gas.
- (57) Assume \$.03 per kwh.
- (58) Assume \$.50 per kgal.
- (59) Include all costs, both contractor and in-house, but do not include in-house labor. Labor is already accounted for in Item (54).
- (60) Include costs as in (26). Assume final disposal cost of \$4.00 per ton of residue. Assume haul distance is 5 miles.
- (61) Assume .75 percent of normalized capital cost.
- (62), (63), &
- (64) Combine these items and assume \$1.00 per throughput ton for all three.

(65) Total annual O and M cost, normalized.

(66) Item (65) divided by Item (16).

(67) Because of the wide differences in resource recovery technologies, the output products from different systems may not at first seem comparable. However, after applying the following assumptions a rough comparison is possible. List the output material in the form that the system design will produce; i.e., #2 ferrous, mixed color glass, 90 percent pure aluminum, mixed metals - 40 percent nonferrous, etc. State the assumed solid waste composition that is used for this determination and be realistic when determining how much of aluminum, mixed metal - 40 percent nonferrous, etc. Then assume the material is worth 75 percent of the Chicago market as of 1 April 1975 for similar material. This is the revenue earned. If there is no Chicago market for the material a judgment as to what the material is worth will have to be made. The rationale for this judgment can be included along with Table VI. The determination of product worth should consider the market price for similar products, possible letters of intent, actual sale price (if product was ever sold) and the like. Do not include shipping.

(68) Assume transportation costs of \$6 per ton for glass; \$12 per ton for ferrous; \$20 per ton for aluminum and other materials at 25 percent of expected revenues.

(69) Sum of material revenues.

(70) Energy products are also difficult to compare. Assume the following prices for energy products.

Steam:	\$1.50/1,000 pounds
Shredded Fuel:	\$.45 per million Btu
Pulped Fuel:	\$.50 per million Btu
Pyrolysis Gas (with useable sensible heat):	\$1.00 per million Btu
Pyrolysis Gas (no sensible heat):	\$1.10 per million Btu
Methane:	\$2.00 per million Btu
Pyrolysis Oil:	\$1.85 per million Btu
Other Chemical:	Average market price as of 1 April 1975
Electricity:	\$.03/kwh

(71) Assume shredded fuel transportation costs at \$.11 per million Btu; zero cost for steam, electricity, and gas (pipes and cables should be included in construction costs); oil at \$.03 per gallon.

(72) Sum of energy revenues.

(73) Item (72) divided by Item (16).

SECTION C-8

DEPARTURES FROM GENERALLY ACCEPTED ACCOUNTING PRINCIPLES (GAAP)

The general format and certain assumptions or concepts applicable to the EPA Accounting Format, (Section C-7), represent departures from Generally Accepted Accounting Principles (GAAP). As a result, the summary amounts representing such items as annual capital costs, and annual operating costs, either in total or on a per Mg (ton) basis, should not be construed as being amounts determined in conformity with GAAP. Some of the subjects in question are as follows:

- o Financing and Legal Costs
- o Land and Depreciation
- o Use of Accrual Accounting Procedures

FINANCING AND LEGAL COSTS

The EPA guidelines provide for the inclusion of financing and legal costs as part of the overall total capital costs. According to the EPA format, these costs are then to be allocated over the estimated useful life of the facility. This has the effect of deferring the impact of the financing and legal costs to accounting periods other than the ones in which they were incurred.

One of the basic principles of accounting involves the matching concept. Simply stated, all items of revenue should be recorded in the accounting period in which they are earned and all items of expense recognized in the period in which they are incurred. Government regulatory agencies permit the inclusion of interest costs during a construction period as a cost of the asset. However, interest is a cost of borrowing funds and not a cost of the asset being constructed.

The effect of including interest as a capital cost results in an overstatement of true capital costs and an understatement of the annual operating expenses.

LAND AND DEPRECIATION

Capital assets, constructed or otherwise acquired, are normally intended to benefit more than one operating year. Such is the case with respect to the capital assets of the Baltimore Plant. As a result, a portion of the cost of these capital assets should be offset in each operating year against

whatever measurable revenues are obtained. This would fulfill the matching principle discussed above. Depreciation achieves this end by allocating the original cost of an item over its estimated useful life.

Included in total capital costs, along with construction costs and equipment, is the cost of the land in which the plant is situated and a portion of the land cost of the landfill site. However, land is a tangible asset that is not subject to depreciation.

The EPA format doesn't provide for including depreciation as an annual operating expense. This obviously has the effect of understating the operating cost category.

USE OF ACCRUAL ACCOUNTING PROCEDURES

During the initial review stages an attempt was made to determine the actual operating costs of the Baltimore Plant. A review of the City accounting system, from which the actual costs were being derived, led to a conclusion that an accrual accounting method was not being employed, neither on a full nor modified basis. (See description of accounting methods under "Description of City Accounting System").

Employment of any basis of accounting other than the full accrual basis is not in conformity with GAAP. Unless expenses and revenues are matched in the periods in which they are experienced, the results are not accurate. This condition was one of the factors which subsequently led to the abandonment of the extraction of incurred operating costs and ultimately use of the scenario approach to project operating and maintenance costs.

RECOMMENDED CHANGES TO EPA's ACCOUNTING FORMAT

Introduction

EPA's Accounting Format depicts the manner in which costs related to the construction and operation of resource recovery facilities should be presented. In accordance with Generally Accepted Accounting Principles the Accounting Format has been analyzed and suggestions for improving the presentation of costs have been offered.

There are two basic ways of organizing costs for presentation or analysis purposes. One method is to present costs in a cost element format (e.g., labor, materials, land, fuel, etc.). EPA's format is somewhat in line with this approach. The second method is to group costs by functional area such as maintenance, operation, general overhead, etc. Under this latter format certain cost elements, such as salaries and employee benefits, appear under each major functional area.

Both methods provide pertinent cost information and no one method has universal application. It cannot be said that one method is preferred over the other. Rather, circumstances and managements needs dictate the use of one method. However, whichever method is chosen, the governing principle must be that of consistency and meaningful presentation.

The Accounting Format side steps these basic principles of accounting when it comes to the treatment of costs. The format's offering of select cost elements is incomplete and inconsistent, especially with the inclusion of functional categories. For example, under "Operation and Maintenance" salary and general overhead cost categories are presented, whereas a material categorization is omitted. In addition, a functional classification such as maintenance is presented, although by definition it includes salary and material related costs.

There are other more obvious inconsistencies with Generally Accepted Accounting Principles (GAAP). Examples of these departures include the treatment afforded contingencies, start-up and working capital costs, financing and legal costs, interest expense, and the absence of depreciation being treated as an annual operating expense.

Contingencies are not capital costs. A cost, capital or operating is not a cost until it actually materializes. This by definition excludes contingencies from this category.

Working capital is a liquid asset requirement to provide a cushion against anticipated operating expenses. It is usually considered necessary until revenues have begun to flow to offset the cash outflow. Therefore, again by definition, this cannot be considered a capital cost.

Financing and legal costs are operating costs and should not be included under the capital cost category.

Interest expense is also included as a capital cost category. Interest expense too is an annual operating expense and a capital cost requirement.

We question the propriety of attempting to ascertain one figure which purportedly represents total costs, a figure which includes capital costs plus operating costs. It must be recognized that these two major cost segments, capital and operating and maintenance, are mutually exclusive and should be treated as such for analysis purposes. Total capital costs can be computed, but these costs should be divorced from operating costs. The total capital investment is normally (in accordance with GAAP) depreciated over some useful life, with some annual portion being included as a normal operating cost. To be meaningful for comparison among facilities, a uniform depreciation policy would also be established for such plant facilities.

The discussion that follows offers suggestions to the format which will facilitate more meaningful economic comparisons of resource recovery systems (in accordance with GAAP).

Capital Costs

The purpose of the capital cost format is to capture and identify all property or asset costs relating to the facility until it has been placed in position and is properly operating. Based on this premise and on our experience from the Landgard economic evaluation, the following changes to the format are recommended (Table C-36).

TABLE C-36. ACTUAL CAPITAL COSTS*

Land	\$ _____
Site preparation	_____
Design	_____
Construction	_____
Real equipment	_____
Other equipment	_____
Total initial capital investment	\$ _____
Additional capital costs due to design modifications	_____
Total capital investment	\$ _____

* In 19__ \$.

As illustrated in Table C-36, the categories of land, site preparation, design, construction, real equipment, and other equipment are included in the format. The only changes to those categories involve their definitions. The definition for each is as follows:

- o Land: Includes land acquisition costs for the facility site and disposal site.
- o Site Preparation: Includes the cost of improvements to the raw land including, but not limited to roads, sidewalks, curbs, and landscaping; in addition to the costs of relocating present tenants and disposal site preparation.
- o Design: Includes but is not limited to consultant and/or contractor costs for preliminary design, feasibility studies, final designs, design drawings, inspection during construction, preparation of operating manuals, operator training, and assistance during start-up.
- o Construction: Includes the cost of construction, material, and labor for the facility, exclusive of equipment purchase and transport costs.
- o Real Equipment: Includes the purchase, transportation, and installation price of plant equipment.
- o Other Equipment: Includes cost of all ancillary equipment like bulldozers, loaders, office equipment, trucks that are necessary for plant operation, and operating spares.

In contrast to EPA's format we have excluded funds set aside for the replacement of depreciated equipment (under EPA's format replacement costs are included in Real Equipment and Other Equipment). First it is unusual for any organization to literally set aside funds on an annual basis for asset replacement. Secondly, these funds cannot be properly labeled capital costs until new assets were actually purchased. As a result, any such fund set aside for asset replacement should not be included as a capital cost.

We have included one additional category, labeled "Additional Capital Costs due to Design Modifications." This category is included in acknowledgement of probable design modifications resulting from the experimental status of resource recovery systems. This category can be further broken down by land, design, real equipment, etc. components.

All other capital cost categories contained in the original format are deleted. As previously described these are not capital costs, and their inclusion would overstate capital costs.

It is also recommended that there should be an omission of capital cost per ton. Through the inclusion of an annual depreciation and interest expense in operating and maintenance, the capital cost will be recognized.

Operation and Maintenance

The major problem with EPA's format categorization of operating and maintenance expenses is that cost elements and functional areas are co-mingled.

The format includes maintenance and residue removal functional classifications. However, these classifications inherently include cost elements such as salaries, fuel, and materials. For analysis purposes, this inconsistent treatment of cost categorizations results in understating either functional costs or cost elements.

Based on the above inconsistencies, a format has been prepared which first allocates costs to functional areas and then further allocates costs to cost elements (Table C-37). This approach incorporates the pertinent cost categories but ameliorates functional cost element inconsistencies.

The revised format omits a category for replacement equipment. A replacement equipment category is unnecessary because any substantial replacement related cost should be treated as a capital asset. We have included a category for expendable assets which cover the cost of minor replacement equipment. These equipment costs are insignificant (less than a specified dollar amount) and expensed in full when incurred.

The other changes to the format involve the inclusion of interest, finance and legal, and depreciation costs, which were previously treated as capital costs.

Other Comments

EPA's revenue format as currently presented, is more than sufficient for economic analysis purposes.

The normalization guidelines in principle also provide for meaningful economic evaluations. The only changes which are recommended involve cost category alterations in accordance with the revised capital and operating and maintenance formats.

TABLE C-37. ACTUAL ANNUAL OPERATING AND MAINTENANCE COSTS*

Operations†		Maintenance†		General§ Administrative		Total
Salaries	\$_____	Salaries	\$_____	Salaries	\$_____	\$_____
Employee benefits	_____	Benefits	_____	Benefits	_____	_____
Fuel	_____	Fuel	_____	Fuel	_____	_____
Electricity	_____	Electricity	_____	Electricity	_____	_____
Water & sewer	_____	Water & sewer	_____	Water & sewer	_____	_____
Materials (Chemicals)	_____	Materials	_____	Materials	_____	_____
Expendable (Assets)	_____	Expendable (Assets)	_____	Expendable (Assets)	_____	_____
Depreciation expense	_____	Depreciation expense	_____	Depreciation expense	_____	_____
				Taxes & Lic.	_____	_____
				Management fees	_____	_____
				Professional services	_____	_____
				Interest expense	_____	_____
				Financing & legal	_____	_____
				Other over- head	_____	_____
Total	\$_____		\$_____		\$_____	\$_____

* In 19__ \$.

† Direct costs.

§ Indirect costs.

SECTION C-9

SUPPLEMENTAL CONSTRUCTION COSTS

The allocation and identification of supplemental construction costs are detailed according to each major piece of equipment (Table C-38).

TABLE C-38. ALLOCATION AND IDENTIFICATION OF SUPPLEMENTAL CONSTRUCTION COSTS

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Shredders		
Venting	76,900	Exclusion
Fenwall explosion system	94,100	Addition
Total	171,000	
Storage and recovery unit		
Distribution chute	8,600	Exclusion
Spreader drive	4,400	Exclusion
Bucket chain	2,500	Exclusion
Floor ramp	5,600	Addition
Bucket wear shoes	14,376	Exclusion
Bucket repair	4,500	Exclusion
Total	39,976	
Waste heat boilers		
Pressure indicators	3,400	Addition
Feedwater valve	5,100	Exclusion
Degasifier pH control	6,900	Exclusion
Blowdown valve platform	300	Addition
Soot blower platforms	12,500	Addition
Ash hopper bridge breakers	4,700	Addition
Jug valve refractory	38,900	Exclusion
Inlet swing gates	97,800	Exclusion
Auxiliary atomizing steam supply*	11,450	Addition
Atomizing steam boiler low pressure alarm	200	Exclusion
Total	181,250	
Refuse combustion air fan		
Air bustle	11,900	Addition
Air bustle	1,100	Exclusion
Total	13,000	
Kiln combustion air fans		
Air bustle	26,500	Exclusion

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Induced draft fan		
Vibration relief	11,400	Exclusion
Corrosion control	3,500	Addition
Foundation reinforcement	2,500	Exclusion
Isolation from ductwork	15,000	Exclusion
Balancing	2,200	Exclusion
Rotor refurbishing	1,500	Exclusion
Dampers	17,900	Exclusion
Dampers	22,500	Addition
Grout*	300	Exclusion
Total	77,300	
Fly ash blower		
Motor	500	Exclusion
Instrument air compressor		
Additional compressor	31,100	Addition
Dust collection fan		
Roof	200	Addition
Cooling water system		
Recycle cooling water system	33,800	Addition
Dust collection system		
Modification	19,800	Exclusion
Kiln		
Flight posts	64,900	Exclusion
Refractory	480,300	Exclusion
Kiln shell	75,800	Exclusion
Fire hood pressure transmitter	700	Exclusion
Feed end seal	4,600	Exclusion
Burner shrouds	8,800	Exclusion
Kiln lube leak	9,000	Exclusion
Spikes	19,700	Exclusion

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Heat control system	13,600	Addition
Burner platform	200	Addition
Burner problems	400	Exclusion
Thermocouples*	1,100	Exclusion
Thermocouples*	1,900	Addition
CO ₂ analyzer*	5,350	Exclusion
Interlocks*	4,500	Addition
Auxiliary atomizing steam supply*	11,450	Addition
Total	702,300	
Gas purifier		
Bafflewall	32,400	Exclusion
Quench air	7,700	Addition
Slag hole lip	4,600	Exclusion
Kiln refractory	35,500	Exclusion
Saddle weld	600	Addition
X-over mixing duct	17,500	Exclusion
Wire instruments	1,900	Addition
Interlocks	4,500	Addition
Thermocouples*	3,000	Exclusion
CO ₂ analyzer*	5,350	Exclusion
Slag removal	10,700	Exclusion
Grout piers*	300	Exclusion
Total	125,050	
Receiving area sump pumps		
Capability	1,900	Exclusion
Storage pit sump pump		
Catch basin	2,300	Exclusion
Scrubber pumps		
Erosion	10,600	Exclusion
Chemical feed pump		
Chem lime caustic pump	2,000	Exclusion

CONTINUED

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Sulfuric acid pump Repair	100	Exclusion
Seal tank		
Slag frit system	16,700	Addition
New pump impeller	3,700	Exclusion
Total	20,400	
Quench tank		
Dump valve	100	Addition
Sedimentation basins	4,500	Addition
Total	4,600	
Gas scrubber		
Control room pH meter	700	Addition
Dust refractory	256,900	Exclusion
Nozzles	12,900	Exclusion
Cyclone	23,600	Addition
Total	294,100	
Thickener		
Scum baffle	600	Addition
Degasifier		
Softener acid lift check	100	Exclusion
Shredder feed conveyors		
Walkway treads	100	Addition
Auto restart	2,000	Exclusion
Total	2,100	
Shredded refuse conveyors		
Bypass gates leak	1,300	Addition

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Clarifier		
Relocate manual valve	2,900	Exclusion
Ram feeders		
Hydraulics	26,500	Exclusion
Mechanical and electrical modifications	8,900	Exclusion
Feed chute	5,100	Addition
TV relocation	3,100	Exclusion
Flow diverter	10,800	Exclusion
Large ram jam alarm	300	Exclusion
Area exhaust system	4,600	Addition
Total	59,300	
Screw conveyors		
Flight repairs	1,600	Exclusion
New transfer screw	23,900	Exclusion
Total	25,500	
Quench tank conveyor		
Replaced	194,300	Exclusion
Magnetic metal separator		
Belt cover	1,200	Exclusion
Modify conveyors*	1,500	Exclusion
Total	2,700	
Aggregate screen conveyor		
Screen cloth	400	Exclusion
Vacuum belt filter		
Glass settling box	1,900	Exclusion
Cloth adjustment platform	200	Exclusion
Total	2,100	

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Char conveyors		
Modify conveyors*	1,500	Exclusion
Roto screen oversize conveyor		
Discharge	700	Exclusion
Interlocks	200	Addition
Conveyors*	1,500	Exclusion
Dumpster guards	1,400	Addition
Total	3,800	
Residue flotation unit		
OSHA catwalks	3,300	Addition
Receiving module		
Tipping floor	5,400	Exclusion
Receiving building venting	800	Addition
Scale house HVAC	300	Addition
Total	6,500	
Thermal processing module		
Gas purifier ductwork	13,700	Exclusion
Energy recovery module		
Steam supply main telemetry system	19,900	Addition
General plant module		
Instrument modifications	100	Exclusion
Heat trace and insulate pipe	25,700	Addition
Painting	28,100	Exclusion
Sewer	24,800	Addition
Site water	2,900	Addition
Miscellaneous†	140,824	
Volt-ohm meter	1,300	Addition
Lift station high level alarm	100	Addition
Total	223,824	

TABLE C-38. (Continued)

Item	Estimated Final Cost (\$)	Exclusion or Addition to Actual Cost
Residue separation module Separation building emer.	500	Exclusion
Storage and recovery module Transfer tower flood drain	1,100	Exclusion

* Allocated to more than one part.

† Broken down by major components with the remaining costs associated to general plant costs.

SECTION C-10

LANDFILL CAPITAL COSTS

Landfill capital costs were derived and allocated based on Pennington Avenue Landfill cost information. (Currently, all residue at the Pyrolysis Plant is disposed of at the Pennington Avenue Landfill).

First, the cost and capacity of the Pennington Avenue Landfill has been determined, yielding a cost per cubic yard. The landfill cost was identified from the Capital Extract and was listed at \$1,782,533. The capacity, as reported by the Department of Public Works was 1,641,221 cubic meters (2,146,636 cubic yard). Therefore, the cost is approximately \$1.09 per cubic meter (\$0.93 per cubic yard).

The next step involved determining the volume necessary for the plant's residue.

Using the annual throughput for each scenario shown in Table C-12 and the estimated useful life of the facility (14.5 years), the total refuse processed over the life of the facility would be:

Scenario 1:	971,500 Mg
Scenario 2:	2,943,500 Mg
Scenario 3:	3,915,000 Mg

The residue from the plant, which is to be disposed at the landfill, consists of kiln residue, gas purifier slag, and fly ash. As discussed previously, the kiln residue averaged 44 percent of the incoming refuse, while the slag and fly ash averaged 1.7 and 0.1 percent of the incoming refuse, respectively. Therefore, approximately 46 percent of the incoming refuse requires landfill disposal. Most of plant residue is comprised of kiln residue and slag which has a bulk density of 1.6 Mg per cubic meter. The total volume of residue over the life of the facility requiring landfill disposal for each scenario is as follows:

Scenario 1:	270,300 cubic meters
Scenario 2:	846,250 cubic meters
Scenario 3:	1,125,550 cubic meters

At \$1.09 per cubic meter, this yields:

Scenario 1:	\$ 304,440
Scenario 2:	\$ 922,410
Scenario 3:	\$1,226,850

These landfill costs were allocated to the EPA classifications on a pro rata basis from the Capital Extract listing. When the \$1,782,533 landfill cost was researched, the costs were broken down as follows:

Extra Work	\$ 195,000
Design	\$ 82,272
Land	\$ 711,291
Inspection	\$ 76,000
Construction	\$ 609,170
Utility Work	\$ 67
Equipment	\$ 100,084
Total	\$1,782,533

The costs associated with the Pyrolysis Plant were allocated on a pro rata basis as shown in Table C-39.

TABLE C-39. ALLOCATION OF LANDFILL COSTS

Actual	Percent	1st Scenario	2nd Scenario	3rd Scenario	EPA Classification
Extra work	11	\$ 33,065	\$ 99,447	\$ 132,259	Cost not categorized
Design	5	15,029	45,217	60,118	Design
Land	40	120,236	361,735	480,943	Land
Inspection	4	12,024	36,173	48,094	Design
Construction	34	102,200	307,474	408,801	Construction
Utility work	0				
Equipment	6	18,035	54,260	72,141	Real Equipment
Total		300,589	904,336	1,202,356	

Table C-46 for the Supplemental Agreement. The allocation of equipment items to cost centers concurs with EPA's classification in the RFP.

TABLE C-40. MONSANTO COST CODING DEFINITIONS

Code	Description	Amount
110	Engineering	\$ 1,201,094
220	Procurement	6,224,143
330	Subcontract site clearing, grade, & road subbases	329,668
331	Subcontract fencing	16,483
332	Subcontract piling	298,590
333	Subcontract foundations & concrete pavings	1,324,520
335	Design, fab, & erect misc bldg shell	296,296
336	Design, fab, & erect Atlas shredded bldg	189,153
337	Subcontract mechanical equip, duct, pipe & steel	2,202,952
338	Subcontract underground piping	75,942
340	Subcontract electrical work above ground	200,097
341	Subcontract electrical work underground	200,569
342	Subcontract instrument work	259,546
343	Subcontract insulation	138,150
344	Subcontract painting	57,894
345	Design and install steam line	1,101,590
346	Subcontract finish road surfacing	42,560
347	Subcontract fine grading and landscaping	46,208
348	Subcontract refractory	303,726
349	Subcontract fire protection & sprinklers	25,401
350	Interior general contractor	91,469
352	Temporary facilities	79,039
359	Checkout & punch list items	36,910
	Total	14,742,000

TABLE C-41. MAJOR EQUIPMENT LIST

Description	Cost Center
Recording Truck Scale	Receiving
Shredders	Size Reduction
Fenwall Explosion Suppression System	Size Reduction
Chemical Feed Tank Agitator	Thermal Processing
Flocculant Feed Tank Agitators, (2)	Thermal Processing
Belt Scale	Thermal Processing
Chelate Tank Agitator	Energy Recovery
Storage and Recovery Unit	Storage and Recovery
Sulfite Tank Agitator	Energy Recovery
Caustic Tank Agitator	Energy Recovery
Waste Heat Boilers, (2)	Energy Recovery
Auxiliary Steam Atomization Boiler	Thermal Processing
Refuse Combustion Air Fan	Thermal Processing
Kiln Combustion Air Fan	Thermal Processing
Steam Turbine	Thermal Processing
Kiln Combustion Air Fan	Thermal Processing
Gas Purifier Combustion Air Fan	Thermal Processing
Crossover Combustion Air Fan	Thermal Processing
Induced Draft Fan	Thermal Processing
Dehumidifier Fans, (6)	Thermal Processing
Separation Air Compressor	Residue Separation
Instrument Air Compressors, (2)	General Plant
Dust Collection Fan	General Plant
Fly Ash Blower	Energy Recovery
Cooling Tower Fan	Thermal Processing
City Water Supply System	General Plant
Cooling Water System	Thermal Processing
Shredder Dust Collectors	Size Reduction
Storage and Recovery Unit Dust Collector	Storage and Recovery
Instrument Air Dryers, (2)	General Plant
Fly Ash Transfer System	Energy Recovery
Transfer Tower Dust Collector	Storage and Recovery
Kiln Feed Dust Collector	Storage and Recovery
Fly Ash Rotary Valves, (12)	Energy Recovery
Fire Protection Water System	General Plant
Kiln	Thermal Processing
Kiln Electric Drive	Thermal Processing
Kiln Emergency Drive	Thermal Processing
Kiln Trunnions	Thermal Processing
Kiln Heat Input Control System	Thermal Processing
Optical Pyrometer	Thermal Processing
Gas Purifier	Thermal Processing
Slag Tap Hole Burner System	Thermal Processing
Kiln Burner System	Thermal Processing

TABLE C-41. (Continued)

Description	Cost Center
Gas Purifier Burner System	Thermal Processing
Kiln Safety Burner System	Thermal Processing
Jug Valve	Energy Recovery
Boiler Swing Gates	Energy Recovery
Boiler Butterfly Valves	Energy Recovery
Fixed Quench Air Damper	Energy Recovery
Butterfly Quench Air Damper	Energy Recovery
Storage Pit Sump Pumps	Receiving
Storage and Recovery Sump Pump	Storage and Recovery
Fuel Oil Pumps	Thermal Processing
Scrubber Pumps	Thermal Processing
Scrubber Strainer	Thermal Processing
Sludge Pump	Thermal Processing
Caustic Pump	Thermal Processing
Flocculant Feed Pump	Thermal Processing
Underflow Pump	Residue Separation
Pressure Pump	Residue Separation
Vacuum Pump	Residue Separation
Filtrate Pump	Residue Separation
Feedwater Pumps, (2)	Energy Recovery
Steam Turbine	Energy Recovery
Clarifier Overflow Sump and Pump	Thermal Processing
Quench Pit Sump Pump	Thermal Processing
Sulfite Pump	Energy Recovery
Chelant Pump	Energy Recovery
Brine Pump	Energy Recovery
Separation Sump Pump	Residue Separation
Sulfuric Acid Pump	Energy Recovery
Degasifier Acid Control	Energy Recovery
Degasifier Pumps, (2)	Energy Recovery
Caustic Pump	Energy Recovery
Degasifier Caustic Control	Energy Recovery
Chemical Unloading Pump	Energy Recovery or
	Thermal Processing
Caustic Transfer Pump	Energy Recovery
Separation Sump Pump	Residue Separation
Wastewater Lift Station Pumps, (2)	General Plant
Seal Tank Recycle Pump	Thermal Processing
Cooling Tower Pump	Thermal Processing
Receiving Basin Pump	Thermal Processing
Plant Drainage System	General Plant
Storage Pit	Receiving
Kiln Feed Hood	Thermal Processing
Kiln Stack Lid	Thermal Processing

TABLE C-41. (Continued)

Description	Cost Center
Kiln Fire Hood	Thermal Processing
Feed End Seal Tank	Thermal Processing
Slag Frit System	Thermal Processing
Residue Quench Tank	Thermal Processing
Fuel Oil Storage Tank	Thermal Processing
Gas Scrubber	Thermal Processing
Scrubber Inlet Nozzles	Thermal Processing
Scrubber Tower Nozzles	Thermal Processing
Scrubber Cyclone	Thermal Processing
Dehumidifier	Thermal Processing
Scrubber Water Tank	Thermal Processing
Clarifier	Thermal Processing
Chemical Feed Tank	Thermal Processing
Flocculant Feed Tanks, (2)	Thermal Processing
Residue Flotation Tank	Residue Separation
Vacuum Receiver	Residue Separation
Thickener	Residue Separation
Water Softeners, (3)	Energy Recovery
Deaerating Heater	Energy Recovery
Degasifier	Energy Recovery
Brine Tank	Energy Recovery
Sulfite Tank	Energy Recovery
Chelate Tank	Energy Recovery
Snubber	Energy Recovery
Steam Purifier	Residue Separation
Caustic Feed Tank	Energy Recovery
Caustic Storage Tank	Energy Recovery
Blowdown Surge Tank	Energy Recovery
Cooling Tower	Energy Recovery
Receiving Basin	Thermal Processing
Steam Separator	Thermal Processing
Seal Tank Recycle Tank	Energy Recovery
Bulldozers	Thermal Processing
Storage Pit Conveyors	Receiving
Shredder Feed Conveyors	Receiving
Shredder Discharge Conveyors	Size Reduction
Shredded Refuse Collecting Conveyor	Size Reduction
Shredded Refuse Elevating Conveyor	Storage and Recovery
Bypass Gates, (2)	Storage and Recovery
Shredded Refuse Transfer Conveyor	Storage and Recovery
Kiln Feed Conveyor	Thermal Processing
Ram Feeders, (2)	Thermal Processing
Ram Diverter Gates, (2)	Thermal Processing
Spillback Screw Conveyor	Thermal Processing

TABLE C-41. (Continued)

Description	Cost Center
Slag Screw Conveyor	Thermal Processing
Transfer Screw Conveyor	Thermal Processing
Slag/Spillback Truck	Thermal Processing
Residue Quench Tank Conveyor	Thermal Processing
Residue Bypass Gate	Residue Separation
Residue Bypass Truck	Residue Separation
Separation Screen	Residue Separation
Separation Screen Cover Plates	Residue Separation
Sinks Discharge Conveyor	Residue Separation
Magnetic Metal Separator	Residue Separation
Magnetic Metal Transfer Conveyor	Residue Separation
Magnetic Metal Truck	Residue Separation
Glassy Aggregate Screen	Residue Separation
Glassy Aggregate Dumpster	Residue Separation
Glassy Aggregate Transfer Conveyor	Residue Separation
Glassy Aggregate Stacker Conveyor	Residue Separation
Glassy Aggregate Traverse Drive	Residue Separation
Vacuum Belt Filter	Residue Separation
Char Transfer Conveyor	Residue Separation
Char Stacker Conveyor	Residue Separation
Char Traverse Drive	Residue Separation
Roto Screen Oversize Conveyor	Residue Separation
Oversize Dumpster	Residue Separation
Mobile Crane	General Plant
Endloader	Residue Separation
Stored Material Spreader	Storage and Recovery
Plant Truck	General Plant
Shop Equipment	General Plant
Spare Parts	General Plant
Magnetic Drum Separator	Storage and Recovery
Vibrating Screen	Storage and Recovery
Vibrating Screen Hopper	Storage and Recovery
Residue Separation Conveyor	Residue Separation
Main Control Panel	General Plant
Electrical System	General Plant
Emergency Power Supply	General Plant

TABLE C-42. ORIGINAL CONTRACT COSTS

Allocation	Cost
110 Engineering	
Operator Training	\$ 27,022
Agitators*	1,986
Storage Pit Hoppers*	795
Shredder Feed and Discharge Conveyors, Shredded Refuse Collection Conveyor*	1,986
Truck Scale*	397
Kiln Hoods*	795
Shredded Refuse Elevating and Transfer Conveyors*	795
Shredders*	795
Various Tanks*	5,165
Kiln Feed Conveyor*	397
Storage and Recovery Unit*	397
Gas Scrubber*	397
Ram Feeders*	795
Belt Scale*	397
Dehumidifier*	397
Screw Conveyors*	795
Clarifier*	397
Residue Quench Tank Conveyor*	397
Waste Heat Boilers*	795
Residue Flotation Tank*	397
Vibrating Screen Conveyors	1,192
Various Fans*	5,165
Vacuum Receiver Unit*	1,192
Sinks Discharge Conveyor*	397
Air Compressors*	795
Thickener*	397
Magnetic Metal Conveyors*	1,192
Dust Collectors*	1,986
Softeners	1,192
Glassy Aggregate Conveyors*	795
Instrument Air Dryer*	397
Deaerating Heater*	397
Vacuum Belt Filter*	397
Fly Ash Transfer System*	397
Degasifier*	397
Char Conveyors*	795
Kiln*	397
Snubber*	397
Stored Material Spreader*	397
Gas Purifier*	397
Magnetic Drum Separator	397
Sump Pumps*	2,384

TABLE C-42. (Continued)

Allocation	Cost
Bulldozers*	795
Burner System*	1,192
Various Pumps*	8,343
Storage Pit Conveyors*	795
Steam Purifier*	397
Various Equipment*	1,986
Preliminary Engineering Flow Sheets	14,898
Final Engineering Flow Sheets	14,898
Special Temporary Power	0
Preliminary Plant Layouts	23,837
Firm Up Plant Layouts	27,810
Issue Fencing Specs. for Quotes	3,937
All Risk and Performance Bonds	64,000
Soils Boring, Site Topo.	993
Site Preparation and Spec. DWGS.	7,350
Analyze Bids and Award Site Prep. Subcontract	795
Prepare Piling Pkg. Specs.	13,508
Analyze Bids and Award Piling Subcontract	795
Final Drawings, Receiving, Size Reduction, and Storage and Recovery modules	3,973
Complete Concrete Drawings, Receiving, Size Reduction, and Storage and Recovery modules, Scope	35,557
Final Drawings, Thermal Processing module	3,937
Base CPM Schedule	13,243
Complete Concrete Drawings, Thermal Processing module, Scope	29,399
Issue Scrubber Concrete Bid Pkg.	0
Analyze Bids and Award Concrete S/C for Scrubber	795
Complete Concrete Drawings, Residue Separation module, Scope	10,330
Analyze Bids and Award Concrete S/C	795
Complete Concrete Drawings, Energy Recovery module, Scope	15,892
Final Drawings, Residue Separation module	3,973
Final Drawings, Energy Recovery module	3,973
Complete Concrete Drawings, General Plant module, Scope	11,124
Final Drawings, General Plant module	3,973
Complete Receiving Building FDN Design	13,905
Preliminary Buildings FDN Design, Scope	0
Complete Sew/Cont Building FDN Design	8,740
Complete Maintenance Building FDN Design	2,980
Complete Office Building FDN Design	2,980
Complete Residue Separation Building FDN Design	3,973
Complete Buildings Pkg	27,810

TABLE C-42. (Continued)

Allocation	Cost
Analyze Bids and Award Buildings Subcontract	1,192
Start Underground Plumbing Design	3,973
Complete Underground Plumbing Design	3,973
Complete Steel Design, Receiving, Size Reduction, Storage and Recovery modules, and Thermal Processing module	62,772 35,955
Analyze Bids and Award Job and Erection S/C	1,391
Complete Steel Design, Residue Separation module	24,235
Energy Recovery module	22,646
General Plant module	29,002
Design Platework and Charter	66,149
Spec. Control Panel and Arrangement	7,946
Instrument List	13,905
Start Loop Sheets	9,336
Complete Initial Design Loop Sheets	9,536
Spec. Control Valves	11,919
Panel Initiation and Trans. Specs.	19,586
Local Initiation Spec. and Drawings	18,673
Back of Panel Drawings	8,939
Local Initiation Installation Drawings	18,871
Specify Insulation Package	3,973
Spec. for Painting Package	3,973
Issue Specs. for Fire Protection	1,986
Issue Specs. for Final Paving - Landscaping	3,973
Complete Ductwork Design, Receiving, Size Reduction, and Storage and Recovery modules	3,973
Complete Ductwork Support Drawings	7,946
Complete Ductwork Design, Thermal Processing, and Energy Recovery modules	7,946
Complete Design, Receiving, Size Reduction, and Storage and Recovery modules	5,959
Thermal Processing module	18,673
Analyze Bids and Award Piping S/C	3,575
Complete Piping Design, Residue Separation module	10,727
Energy Recovery module	23,440
General Plant module	21,851
Scope and Spec. Steam System	7,946
Start Underground Elec. and Grounding Design	13,508
Complete Underground Elec. and Grounding Design	13,508
Analyze Bids and Award Steam System S/C	1,589
Analyze Bids and Award U.G. Electrical S/C	0
Start One-Line Diagram, Receiving, Size Reduction, Storage and Recovery, Thermal Processing, Residue Separation, Energy Recovery, and General Plant modules	6,357

TABLE C-42. (Continued)

Allocation	Cost
Complete One-Line Diagram, Receiving, Size Reduction, Storage and Recovery, Thermal Processing, Residue Separation, Energy Recovery, and General Plant modules	9,535
Spec. Balance of Elec. Equipment (PWR, LTG)	173,221
Prepare Motor List	1,986
Spec. Switchgears, Transformers, Generator	2,304
Scope and Prepare Mechanical Erection Package	3,973
Operation Manuals	26,486
Total	1,201,094
220 Procurement	
Recording Truck Scale	29,366(265)
Shredders	498,980(265)
Chemical and Flocculant Feed Tank Agitators	3,939(265)
Belt Scale	6,914(265)
Chelate Tank Agitator	730(265)
Storage and Recovery Unit (60,000)	225,288(265)
Sulfite Tank Agitator	265 --- -
Flocculant Feed Tank Agitator	396(265)
NaOH Storage Tank Agitator	640(265)
Waste Heat Boilers	697,856(265)
Refuse Combustion Air Fan	4,894(265)
Kiln Combustion Air Fans	9,860(265)
Gas Purifier Combustion Air Fan	8,805(265)
Crossover Combustion Air fan	11,582(265)
Dust Collection Fan	4,249(265)
Induced Draft Fan	129,859(265)
Dehumidifier Fans	107,252(265)
Separation Air Compressor	4,865(265)
Instrument Air Compressor	7,843(265)
Shredder Dust Collector	14,828(265)
Storage, Trans, Kiln-Dust Collector	6,849(265)
Instrument Air Dryer	2,813(265)
Fly Ash Transfer System	21,842(265)
Kiln	736,217(265)
Gas Purifier	79,896(265)
Kiln Burner System	98,257(265)
Gas Purifier Burner System	41,023(265)
Kiln Safety Burner System	32,400(265)
Storage Pit Sump Pump	1,423(265)
Storage and Recovery Unit Sump Pump	1,428(265)
Fuel Oil Pumps	1,555(265)

TABLE C-42. (Continued)

Allocation	Cost
Scrubber Pumps	29,440(265)
Sludge Pump	2,084(265)
Chemical Feed Pump	1,555(265)
Flocculant Feed Pump	1,423(265)
Underflow Pump	1,687(265)
Pressure Pump	6,949(265)
Vacuum Pump	8,390 -
Filtrate Pump	1,480 -
Feedwater Pump	12,905(265)
Clarifier Overflow Sump Pump	1,555(265)
Quench Pit Sump Pump	1,423(265)
Sulfite Pump	497(265)
Chelate Pump	497(265)
Brine Pump	1,687(265)
Separation Sump Pump	1,423(265)
Sulfuric Acid Pump	1,687 -
Degasifier Pump	1,423(265)
NaOH Pump	1,687 -
Chemical Unloading Pump	2,084(265)
Degasifier Pump	1,423(265)
Storage Pit Sump Pump	1,423(265)
NaOH Storage Tank Pump	1,180(265)
Storage Pit Hoppers	29,902(265)
Kiln Feed and Fire Hoods	44,848(265)
Seal Tank	14,857(265)
Residue Quench Tank	27,921(265)
Fuel Oil Storage Tank	14,986(265)
Dehumidifier	224,420(265)
Clarifier	39,961(265)
Chemical Feed Tank	7,876(265)
Flocculant Feed Tank	3,249(265)
Residue Flotation Unit	20,942(265)
Vacuum Receiver	1,960(265)
Thickener	41,861(265)
NaOH Storage Tank	12,400(265)
Water Softeners	40,900(265)
Deaerating Heater	21,842(265)
Degasifier	19,919(265)
Brine Tank	6,924(265)
Sulfite Tank	1,361(265)
Chelate Tank	1,361(265)
Snubber	250(265)
NaOH Tank	1,823(265)
Flocculant Feed Tank	796(265)

TABLE C-42. (Continued)

Allocation	Cost
Bulldozers	137,571(265)
Storage Pit Conveyors	99,596(265)
Shredder Feed Conveyors	129,078(265)
Shredder Discharge Conveyors	37,747(265)
Shredded Refuse Conveyors	236,444(265)
Kiln Feed Conveyor	48,830(265)
Ram Feeders	113,824(265)
Screw Conveyors	12,812(265)
Residue Quench Tank Conveyor	28,559(265)
Separation Screen	9,695(265)
Sinks Discharge Conveyor	4,868(265)
Magnetic Metal Separation System	39,800(265)
Glassy Aggregate Screen	9,860(265)
Glassy Aggregate Transfer Conv.	49,975(265)
Vacuum Belt Filter	74,640(265)
Char Transfer Conveyors	48,330(265)
Mobile Crane	27,117(265)
Endloader	41,403(265)
Stored Material Spreader	21,165(265)
Plant Truck	7,275(265)
Shop Equipment	45,747(265)
Magnetic Drum Separator	38,456(265)
Vibrating Screen Conveyor	13,228(265)
2 Shredder Motors and Starters	32,600(265)
13. 2KV/480-277V Substation	153,710(265)
Emergency Power Supply	16,270(265)
5 Motor Control Centers	47,489(265)
5 Motor Starters	25,662(265)
Ductwork, Receiving, Size Reduction, and	
Storage and Recovery modules	19,445(265)
Thermal Processing module	79,897 -
Energy Recovery module	76,326 -
Butterfly Valve, Thermal Processing module	11,112(265)
Energy Recovery module	64,024(265)
Jug Valve, Energy Recovery module	29,102(265)
Gate Valves, Energy Recovery module	21,165(265)
Main Control Panel	86,643(265)
Local Instruments, Receiving, Size Reduction,	
and Storage and Recovery modules	19,842(265)
Thermal Processing module	39,684 -
Residue Separation module	29,895 -
Energy Recovery module	50,531 -
General Plant module	13,625(265)
Spare Parts	250,000(265)

TABLE C-42. (Continued)

Allocation	Cost
Equipment Platework	47,884 (265)
Structure, Platform, and Misc. Steel, Receiving, Size Reduction, and Storage and Recovery modules	156,884 (265)
Thermal Processing module	127,253 -
Residue Separation module	15,476 -
Energy Recovery module	13,757 -
Office Building Steel	4,894 -
Total	6,224,143
330 Subsite Clear, Grade and Road Sub-Bases	
Grading of Site for All modules	290,486
Install Road Sub-Bases, General Plant module	27,022
Install Parking Lot Sub-Bases, General Plant module	9,458
Complete Dike, General Plant module	2,702
Total	329,668
331 Subfencing	
Install Fencing, General Plant module	16,483
Total	16,483
332 Subpiling	
Drive Piles as Required, Receiving, Size Reduction, and Storage and Recovery modules	201,285
Thermal Processing module	70,608
Residue Separation module	9,485
Energy Recovery module	7,552
General Plant module	9,660
Total	298,590
333 Subfoundation and Concrete Paving	
Start Excavation Receiving Building, Receiving, Size Reduction, and Storage and Recovery modules	6,755
Complete Excavation Receiving Building, Receiving, Size Reduction, and Storage and Recovery modules	6,755
Foundations - Receiving Building Footings, Receiving, Size Reduction, and Storage and Recovery modules	85,410

TABLE C-42. (Continued)

Allocation	Cost
Complete Footings and Walls	152,741
Install Gallery Conveyor Foundations, Shredder Feed Conveyors	15,308
Line Grading for Slab, Receiving, Size Reduction, and Storage and Recovery modules	6,755
Pour Pit Slabs, Receiving, Size Reduction, and Storage and Recovery modules	113,728
Pour Slabs Receiving Building	113,728
Install Shredder Foundations	41,634
Install Storage and Recovery Unit Foundation	81,350
Install Truck Scale Foundation Scale House	17,159
Balance of Equip. Conveyors Foundations Supports	25,394
Install Gas Purifier Foundations	4,607
Install Dehumidifier, Clarifier Overflow Sump Foundations	11,937
Install Foundations for Seal and Residue Quench Tanks	14,450
Start Excavations, Thermal Processing module	6,755
Start Kiln Foundations	54,429
Install Scrubber Foundations	18,111
Complete Pump Foundation Excavation	1,351
Complete Foundations for Kiln and Kiln Hoods	78,431
Erect Scrubber Concrete Structure	145,014
Install Quench Pit Sump	2,702
Install Pump Foundations	12,342
Install Fan Foundations	12,119
Install Foundations for Sludge and Caustic Pumps and Flocculant Feed Tank	2,634
Install Clarifier Foundations and Slab	11,214
Install Clarifier Platework	3,432
Install Ram Feeders Support Foundations	2,027
Install Screw Conveyors Support Foundations	723
Start Excavations, Residue Separation module	4,053
Complete Excavations, Residue Separation module	4,053
Residue Separation Building Foundation	22,036
Complete Residue Building Slab	4,817
Install Separation Compressor Foundation	203
Install Foundation for Underflow and Pressure Pumps	676
Install Thickener Foundation and Slab	22,881
Install Thickener Platework	21,584
Install Vacuum Belt Filter Foundation	676
Install Foundation for Char Conveyors	1,054
Install Magnetic Metal Separation System Foundation	723
Start Excavations, Energy Recovery module	4,053

TABLE C-42. (Continued)

Allocation	Cost
Complete Excavations, Energy Recovery module	4,053
Control/Water Treat Building Foundation	39,108
Install Brine Tank Foundation	1,385
Control/Water Treat Building Int. Slabs	29,218
Install Fly Ash Collection System and Ductwork	
Support Foundations	2,702
Install Foundations for Waste Heat Boilers	13,369
Install Deaerating Heater	4,682
Excavation-Substations	1,351
Install Substation Foundations Slab, General	
Plant module	9,458
Start Office Building Foundation, General Plant	
module	8,053
Complete Office Building Slab, General Plant module	14,315
Start Maintenance/Storage Buildings. FDNs, General	
Plant module	14,389
Complete Maintenance Building Slabs, General Plant	
module	32,588
Install Fuel Oil Storage Tank Foundations	13,369
Install Fuel Oil Pumps Foundations	676
Total	1,324,520
335 Design, Fab, and Erect Misc. Building Shell	
Install Scale Building	3,243
Erect Receiving Building Steel	81,066
Complete Siding Etc. - Receiving Building, Receiving,	
Size Reduction, and Storage and Recovery modules	87,822
Install Residue Separation Building Steel Skin, Residue	
Separation module	6,755
Erect Water Treatment Building Structural Steel	5,404
Complete Water Treat Building Roofing, Steel, and	
Siding	6,755
Erect Control House Steel	9,458
Complete Steel Siding on Control House, Energy Recovery	
module	10,809
Erect Office Building Steel Siding, General Plant module	56,746
Storage/Maintenance Building Struct Steel Erect	16,078
Complete Building Exterior, General Plant module	12,160
Total	296,296

TABLE C-42. (Continued)

Allocation	Cost
336 Design, Fab, and Erect Atlas Shredded Building	
Install Storage and Recovery Unit	189,153
Total	189,153
337 Submechanical Equipment, Duct, Pipe, and Steel	
Install Truck Scale	19,996
Start Transfer HSE Steel	6,755
Complete Transfer HSE Steel	6,755
Start Conveyor Gallery Steel, Receiving, Size Reduction, and Storage and Recovery modules	41,580
Continue Gallery Steel, Receiving, Size Reduction, and Storage and Recovery modules	40,533
Shredder House and Gallery Siding, Receiving, Size Reduction, and Storage and Recovery modules	39,587
Install Ductwork, Receiving, Size Reduction, and Storage and Recovery modules	23,705
Install Shredder House Steel	23,313
Install Storage Pit, Shredder Feed Conveyors, and Chutes	58,773
Complete Conveyors Trim-out, Storage Pit, and Shredder Feed Conveyors, Receiving, Size Reduction, and Storage and Recovery modules	6,775
Install Storage Pit Hoppers	11,167
Install Shredders	36,635
Install Shredder Dust Collectors, Shredder Discharge Conveyors, Shredded Refuse Collection Conveyor Chutes	28,211
Install Sump Pumps	1,324
Install Bal of Equipment Kiln Feed Conveyor, Belt Scale, Screens, and Chute	16,260
Trim Out Shredded Refuse Elevating and Transfer Conveyor, Stored Material Spreader	6,755
Trim Out Conveyors, Receiving, Size Reduction, and Storage and Recovery modules	2,027
Install Dust Collectors, Chutes	52,875
Start Piping, Receiving, Size Reduction, and Storage and Recovery modules	31,497
Complete Piping, Receiving, Size Reduction, and Storage and Recovery modules	31,504
Erect Scrubber Accessory Steel	8,816
Erect Kiln Fd. HSE Fire Hood Support	13,511
Erect Conveyor Support	14,092
Install Fire Hood Siding	4,188
Install Sump Pumps	2,135

TABLE C-42. (Continued)

Allocation	Cost
Erect Duct Support, Dehumidifier Support	25,671
Erect Kiln Platforms and Ladders	25,671
Install Dehumidifier	50,349
Install Gas Purifier	34,676
Erect Dehumidifier Fans	6,661
Erect Gas Purifier Burner System	28,995
Erect Kiln	160,646
Erect Scrubber Internals	6,755
Erect Combustion Fans	12,146
Erect Induced Draft Fan	0
Erect Kiln Hoods	8,819
Erect Kiln Burner Systems	43,296
Erect Seal and Residue Quench Tanks	15,673
Install Refractory for Kiln Hoods	151,053
Install Refractory in Ducts, Thermal Processing module	64,177
Install Clarifier Mechanical	5,485
Erect Pumps	19,584
Erect Ram Feeders	5,485
Erect Chemical Feed Tank	979
Start Install Ductwork, Thermal Processing module	55,932
Erect Flocculant Feed Tank	588
Erect Screw Conveyors	9,795
Install Agitators	1,371
Complete Ductwork, Thermal Processing module	55,933
Start Piping, Thermal Processing module	68,078
Complete Piping, Thermal Processing module	66,726
Install Residue Flotation Tank Platework	4,506
Install Residue Separation Screen and Platework	1,567
Install Magnetic Metal Separation System Conveyors, and Platework	5,877
Install Glassy Aggregate Screen and Platework	980
Install Magnetic Metal Conveyors	6,269
Install Sump Pump	392
Erect Res. Building Int. Support	6,755
Complete Structural and Platform Steel, Residue Separation module	5,979
Install Foundations for Glassy Aggregate conveyors	2,966
Install Separation Air Compressor	784
Install Pressure and Underflow Pumps	980
Install Thickener Mechanical Equipment and Platework	25,076
Install Vacuum Filter Assembly	3,135
Install Char Conveyors and Platework	9,208
Install Glassy Aggregate Conveyors	10,971
Conveyor Trim-Outs, Residue Separation module	13,511

TABLE C-42. (Continued)

Allocation	Cost
Start Piping Above Ground, Residue Separation module	11,536
Complete Piping, Residue Separation module	11,535
Piping Tests, Residue Separation module	1,351
Install Brine Pump	196
Install Plumbing	6,458
Erect Instrument Air Compressor	0
Erect Deaerating Heater	2,155
Start Ductwork, Energy Recovery module	54,168
Install Dust Collectors	9,795
Complete Ductwork, Energy Recovery module	54,170
Erect Waste Heat Boilers	13,511
Erect Feedwater Pumps	4,506
Complete Boiler Installation	57,212
Install Boiler Refractory	46,883
Erect Misc. Steel, Energy Recovery module	5,191
Complete Misc. Steel, Energy Recovery module	5,192
Erect Degasifier System Pumps	1,385
Final Align Test Group, Energy Recovery module	1,351
Erect Boiler Chemical Pumps	392
Erect Tanks in Water Treatment Building	1,642
Erect Softeners	6,073
Erect Agitators	196
Erect Caustic Feed Tank	392
Erect Degasifier	4,506
Start Piping Erection, Energy Recovery module	54,236
Erect Brine Tank	0
Continue Piping, Energy Recovery module	54,236
Install Instrument Air Compressor and Dryer, Energy Recovery module	7,249
Complete Piping Erection, Energy Recovery module	54,237
Final Piping Testing, Energy Recovery module	12,471
Install Above Ground Steam System Lines	40,530
Install Steam Purifier	9,808
Underground Sewers	13,999
Install Plumbing	4,324
Install Spare Parts Warehouse (By Client)	0
Install Shop Items	21,618
Set-Up Equipment	784
Erect Fuel Oil Pumps	588
Erect Fuel Oil Tank	9,728
Complete Piping, Tanks, and Pumps, General Plant module	39,809
Install Fuel Oil Line to Burners, General Plant module	20,537

TABLE C-42. (Continued)

Allocation	Cost
Test Fuel Oil System, General Plant module	6,755
Total	2,202,952
338 Subunderground Piping	
Install Cont/Water Treat O/G Sewers and Water	13,999
Install Underground Fire Loop and Test, General Plant module	39,234
Install Underground Process Water, General Plant module	20,007
Install Monitors, General Plant module	0
Complete Backfill Tests, General Plant module	2,702
Total	75,942
340 Subelectrical Work Above Ground	
Install Above Ground Electrical Hookups, Receiving, Size Reduction, and Storage and Recovery modules	37,831
Complete Electrical Hookups, Receiving, Size Reduction, and Storage and Recovery modules	7,566
Final Electrical Works Testing, Receiving, Size Reduction, and Storage and Recovery modules	5,404
Start Above Ground Electrical, Thermal Processing module	33,777
Complete Above Ground Electrical Thermal Processing module	33,777
Install Above Ground Electrical	33,102
Electrical Hook-Ups, Residue Separation module	8,107
Start Electrical, Energy Recovery module	13,511
Continue Electrical, Energy Recovery module	13,511
Complete Electrical, Energy Recovery module	13,511
Total	200,097
341 Subelectrical Work Underground	
Install Building Underground Electrical, Receiving, Size Reduction, and Storage and Recovery modules	20,267
Install Grounding, Receiving, Size Reduction, and Storage and Recovery modules	13,511
Install Underground Power, Thermal Processing module	13,511
Install Building Underground Electrical, Residue Separation module	2,702

TABLE C-42. (Continued)

Allocation	Cost
Install Underground Power Etc., Residue Separation module	9,458
Grounding, Residue Separation module	6,755
Install Cont/Water Treat U/G Elect	13,511
Install Primary Underground Feeders, General Plant module	24,320
Set 4.16 KV Equipment, General Plant module	4,053
Set 480V Equipment, General Plant module	6,755
Complete 4.16 KV Connections, General Plant module	13,511
Complete 480V Connections, General Plant module	13,511
Start Site Lighting	16,213
Continue Site Lighting	16,213
Complete Site Lighting	16,213
Complete Electrical Tie-Ins, Etc., General Plant module	10,065
Total	200,569
342 Subinstrumentation Work	
Start Instrumentation, Receiving, Size Reduction, and Storage and Recovery modules	20,267
Complete Instrumentation, Receiving, Size Reduction, and Storage and Recovery modules	20,267
Start Instrumentation, Thermal Processing module	23,644
Complete Instrumentation, Thermal Processing module	25,671
Start Instrumentation, Residue Separation module	22,939
Complete Instrumentation, Residue Separation module	22,939
Start Instrumentation, Energy Recovery module	22,443
Continue Instrumentation, Energy Recovery module	22,443
Complete Instrumentation, Energy Recovery module	22,443
Set Panel, Energy Recovery module	9,863
Complete Panel Hook-Ups, Check Out, Energy Recovery module	22,239
Start Instrumentation, General Plant module	12,194
Complete Instrumentation, General Plant module	12,194
Total	259,546
343 Subinsulation	
Insulation, Receiving, Size Reduction, and Storage and Recovery modules	21,618
Insulation, Thermal Processing module	28,238

TABLE C-42. (Continued)

Allocation	Cost
Painting, Thermal Processing module	24,117
Insulation, Residue Separation module	2,702
Insulation, Energy Recovery module	51,342
Insulation, General Plant module	10,133
Total	138,150
344 Subpainting	
Painting, Receiving, Size Reduction, and Storage and Recovery modules	24,117
Painting, Residue Separation module	10,268
Painting, Energy Recovery module	16,754
Painting, General Plant module	6,755
Total	57,894
345 Design and Install Steam Line	
Install U.G. Steam Line to City of Baltimore	973,236
Install Steam Line at R.R. Trestle	101,332
Complete and Test Steam System	27,002
Total	1,101,590
346 Sub Finish Road Surfacing	
Install Permanent Roads	33,102
Install Permanent Parking Lot	9,458
Total	42,560
347 Subfine Grading and Landscaping	
Landscaping	46,208
Total	46,208
348 Subrefractory	
Install Gas Purifier Brick Linings	49,180
Install Kiln Internals	0
Install Kiln Brick Linings	254,546
Total	303,726

TABLE C-42. (Continued)

Allocation	Cost
349 Subfire Protection and Sprinklers	
Install Sprinklers	25,401
Total	25,401
350 Building Interior General Contractor	
Install Receiving Building Arch Spec.	29,319
Complete Building Trim and Control Boiler House	17,024
Complete Building Trim, Etc.	6,755
Complete Building, Interior Trim, General Plant module	4,729
Install Office Furniture, General Plant module	6,755
Complete Building Trim, General Plant module	26,887
Total	91,469
352 Temporary Facilities	
Mobilize On Site and Set-Up Temporary Facilities	79,039
Total	79,039
359 Checkout and Punch-List Items	
Final Run-Ins Testing, Receiving, Size Reduction, and Storage and Recovery modules	6,755
Thermal Proecssing module	6,755
Residue Separation module	2,702
Energy Recovery module	20,266
Complete Final Punch Lists, General Plant module	432
Total	36,910
Grand Total	14,742,000

* Prepare process design sheets.

TABLE C-43. ORIGINAL CONTRACT CAPITAL COSTS

Recording truck scale	
(110)	\$ 397
(220)	29,631
(333)	17,159
(337)	19,996
Total	67,183
Shredders	
(110)	794
(220)	499,245
(333)	41,634
(337)	36,635
Total	578,308
Chemical and floc feed tank agitators	
(110)	794
(220)	4,204
(337)	1,371
Total	6,369
Conveyor scale	
(110)	397
(220)	7,179
(337)	2,017
Total	9,593
Chelate tank agitator	
(110)	397
(220)	995
Total	1,392
Storage and recovery unit	
(110)	397
(220)	285,553
(333)	81,350
Total	367,300

TABLE C-43. (Continued)

Sulfite tank agitator	
(110)	397
(220)	265
Total	662
Floc feed tank agitator	
(110)	397
(220)	661
Total	1,058
NaOH storage tank agitator	
(220)	905
Waste heat boilers	
(110)	795
(220)	698,121
(333)	13,369
(337)	13,511
	57,212
	46,883
Total	829,891
Refuse combustion air fan	
(110)	397
(220)	5,159
(333)	359
(337)	360
Total	6,275
Kiln combustion air fans	
(110)	795
(220)	10,125
(333)	724
(337)	726
Total	12,370

TABLE C-43. (Continued)

Gas purifier combustion air fan		
(110)		397
(220)		9,070
(333)		647
(337)		648
Total		10,762
Crossover combustion air fan		
(110)		397
(220)		11,847
(333)		851
(337)		853
Total		13,948
Dust collection fan		
(110)		397
(220)		4,514
Total		4,911
Induced draft fan		
(110)		397
(220)		130,124
(333)		9,538
(337)		9,559
Total		149,618
Dehumidifier fans		
(110)		2,384
(220)		107,517
(337)		4,996
Total		114,897
Separation air compressor		
(110)		398
(220)		203
(337)		5,130
		833
		784
Total	342	7,348

TABLE C-43. (Continued)

Instrument air compressor		
(110)		398
(220)		8,108
(337)		833
		5,335
Total		14,674
Shredder dust collector		
(110)		794
(220)		15,093
(337)		3,184
Total		19,071
Storage, trans, kiln dust collectors		
(110)		1,192
(220)		7,114
(337)		1,951
Total		10,257
Instrument air dryer		
(110)		397
(220)		3,078
(337)		1,118
		1,914
Total		6,507
Fly ash transfer system		
(110)		397
(220)		22,107
(333)		2,705
(337)		8,677
Total		33,886
Kiln		
(110)		397
(220)		736,482
(333)		54,429
		73,928
(337)	343	25,671

TABLE C-43. (Continued)

(348)	160,646
	284,656
Total	1,336,209
Gas purifier	
(110)	397
(220)	80,161
(333)	4,607
(337)	36,676
(348)	49,180
Total	171,021
Kiln burner system	
(110)	397
(220)	98,522
(337)	32,560
Total	131,479
Gas purifier burner system	
(110)	397
(220)	41,288
(337)	28,995
Total	70,680
Kiln safety burner system	
(110)	397
(220)	32,665
(337)	10,736
Total	43,798
Receiving area sump pump	
(110)	397
(220)	1,688
(337)	331
Total	2,416

TABLE C-43. (Continued)

Storage pit sump pump	
(110)	397
(220)	1,693
(337)	332
Total	2,422
Fuel oil pumps	
(110)	795
(220)	1,820
(333)	676
(337)	588
Total	3,879
Scrubber pumps	
(110)	795
(220)	29,705
(333)	8,547
(337)	15,169
Total	54,216
Sludge pump	
(110)	397
(220)	2,349
(333)	813
(337)	1,074
Total	4,633
Chemical feed pump	
(110)	397
(220)	1,820
(333)	451
(337)	801
Total	3,469
Floc feed pump	
(110)	397
(220)	1,688
(333)	555

TABLE C-43. (Continued)

(337)	733
Total	3,373
Underflow pump	
(110)	397
(220)	1,952
(333)	132
(337)	191
Total	2,672
Pressure pump	
(110)	397
(220)	7,214
(333)	544
(337)	789
Total	8,944
Vacuum pump	
(110)	596
(220)	8,390
(337)	303
Total	9,289
Filtrate pump	
(110)	596
(220)	1,480
(337)	54
Total	2,130
Feedwater pumps	
(110)	795
(220)	13,170
(337)	4,506
Total	18,471
Pump	
(110)	397

TABLE C-43. (Continued)

Pump		
(110)		397
Clarifier overflow sump pump		
(110)		397
(220)		1,820
(333)		82
		451
(337)		1,115
Total		3,865
Quench pit sump pump		
(110)		397
(220)		1,688
(333)		2,702
(337)		1,020
Total		5,807
Sulfite pump		
(110)		397
(220)		762
(337)		196
Total		1,355
Chelate pump		
(110)		397
(220)		762
(337)		196
Total		1,355
Brine pump		
(110)		397
(220)		1,952
(337)		196
Total		2,545
Separation sump pump		
(110)		397

TABLE C-43. (Continued)

(220)	1,688
(337)	392
Total	2,477
Sulfuric acid pump	
(110)	397
(220)	1,687
(337)	281
Total	2,365
Degasifier pump	
(110)	397
(220)	1,688
(337)	237
Total	2,322
NaOH pump	
(110)	397
(220)	1,687
(337)	281
Total	2,365
Chemical unloading pump	
(110)	397
(220)	2,349
(333)	605
(337)	1,074
	348
Total	4,773
Degasifier pump	
(110)	397
(220)	1,688
(337)	331
	733
	237
Total	3,386

TABLE C-43. (Continued)

Storage pit sump pump	
(110)	397
(220)	1,688
(337)	331
Total	2,416
NaOH storage tank pump	
(220)	1,145
Storage pit hopper	
(110)	795
(220)	30,167
(337)	11,167
Total	42,129
Kiln feed and fire hoods	
(110)	795
(220)	45,113
(333)	4,503
(337)	13,511
	4,188
	8,819
	151,053
Total	227,982
Seal tank	
(110)	430
(220)	15,122
(333)	5,019
(337)	5,443
Total	26,014
Residue quench tank	
(110)	430
(220)	28,186
(333)	9,431
	10,230
Total	48,277

TABLE C-43. (Continued)

Fuel oil storage tank	
(110)	430
(220)	15,251
(333)	13,369
(337)	9,728
Total	38,778
Gas scrubber	
(110)	397
	795
(333)	18,111
	145,014
(337)	8,816
	6,755
Total	179,888
Dehumidifier	
(110)	397
(220)	224,685
(333)	11,855
(337)	50,349
	25,671
Total	312,957
Clarifier	
(110)	397
(220)	40,226
(333)	11,214
	3,432
(337)	5,485
Total	60,754
Chemical feed tank	
(110)	430
(220)	8,141
(333)	2,287
(337)	979
Total	11,837

TABLE C-43. (Continued)

Floc feed tank	
(110)	430
(220)	3,514
(333)	1,267
(337)	588
	858
Total	6,657
Residue flotation unit	
(110)	397
(220)	21,207
(337)	4,506
Total	26,110
Vacuum receiver	
(220)	2,225
(337)	71
Total	2,296
Thickener	
(110)	397
(220)	42,126
(333)	22,881
	21,584
(337)	25,076
Total	112,064
NaOH storage tank	
(220)	12,665
Water softeners	
(110)	430
	795
(220)	41,165
(337)	6,073
Total	48,463

TABLE C-43. (Continued)

Derating heater	
(110)	397
(220)	397
(333)	22,107
(337)	4,682
	1,115
Total	29,698
Degasifier	
(110)	397
(220)	20,184
(337)	4,506
Total	25,087
Brine tank	
(110)	430
(220)	7,189
(333)	1,385
Total	9,004
Sulfite tank	
(110)	430
(220)	1,626
(337)	359
Total	2,415
Chelate tank	
(110)	430
(220)	1,626
(337)	359
Total	2,415
Snubber	
(110)	397
(220)	515
(337)	9
	66
Total	987

TABLE C-43. (Continued)

Steam purifier	
(110)	397
(337)	9,808
Total	10,205
Tank	
(110)	430
NaOH tank	
(110)	430
(220)	2,088
(337)	392
Total	2,910
Floc feed tank	
(110)	430
(220)	1,061
Total	1,491
Bulldozers	
(110)	795
(220)	137,836
(337)	506
Total	139,137
Storage pit conveyors	
(110)	795
(220)	99,861
(337)	25,598
	2,951
Total	129,205
Shredder feed conveyors	
(110)	794
(220)	129,343
(333)	15,308
(337)	33,175

TABLE C-43. (Continued)

	3,824
Total	182,444
Shredder discharge conveyors	
(110)	794
(220)	38,012
(337)	8,105
Total	46,911
Shredded refuse conveyors	
(110)	397
(220)	795
(337)	236,709
	16,922
	5,955
	44,896
Total	305,674
Kiln feed conveyor	
(110)	397
(220)	49,095
(337)	14,243
Total	63,735
Ram feeders	
(110)	795
(220)	114,089
(333)	224
(337)	5,485
Total	120,593
Screw conveyors	
(110)	795
(220)	13,077
(333)	224
(337)	3,033
Total	17,129

TABLE C-43. (Continued)

Residue quench tank conveyor	
(110)	397
(220)	28,824
(333)	499
(337)	6,762
Total	36,482
Residue separation screen	
(110)	397
(220)	9,960
(337)	1,567
Total	11,924
Sinks discharge conveyor	
(110)	397
(220)	5,133
(337)	1,155
Total	6,685
Magnetic metal separation conveyors	
(110)	795
(220)	40,065
(333)	723
(337)	4,722
	6,269
Total	52,574
Conveyor	
(110)	397
Glassy aggregate screen	
(110)	397
(220)	10,125
(337)	980
Total	11,502
Glassy aggregate transfer conveyors	
(110)	795

TABLE C-43. (Continued)

(220)	50,240
(337)	2,966
	10,971
Total	64,972
Vacuum belt filter	
(110)	397
(220)	74,905
(333)	676
(337)	2,698
Total	78,676
Char transfer conveyors	
(110)	795
(220)	48,595
(333)	1,054
(337)	9,208
Total	59,652
Mobile crane	
(110)	397
(220)	27,382
(337)	100
Total	27,879
Enloader	
(110)	397
(220)	41,668
(337)	152
Total	42,217
Stored material spreader	
(110)	397
(220)	21,430
(337)	800
	6,028
Total	28,655

TABLE C-43. (Continued)

Plant truck	
(110)	397
(220)	7,540
(337)	27
Total	7,964
Shop equipment	
(110)	397
(220)	46,012
(337)	21,618
Total	68,027
Conveyor	
(110)	397
Magnetic drum separator	
(220)	38,721
Vibrating screen conveyor	
(110)	397
(220)	13,493
Total	13,890

TABLE C-44. NON SPECIFIC COSTS*

Code	Description	Cost
(110)	Final drawings	\$ 3,973
	Complete concrete drawings	35,557
	Complete steel design	62,772
	Complete ductwork design	3,973
	Complete design	5,959
(220)	Local instruments	20,107
	Structures and platforms	157,149
	Ductwork	19,710
(332)	Drive piles as required	201,285
(333)	Line grading for slab	6,755
	Pour pit slabs	113,728
(337)	Install ductwork	23,705
	Trim out conveyors	2,027
	Start piping	31,497
	Complete piping	31,504
(340)	Install above ground electrical hookups	37,831
	Complete electrical hookups	7,566
	Final electrical works testing	5,404
(341)	Install building underground electrical	20,267
	Install grounding	13,511
(342)	Start instrumentation	20,267
	Complete instrumentation	20,267
(343)	Insulation	21,618
(344)	Painting	24,117
(349)	Install sprinklers	25,401
(359)	Final run-ins testing	6,755
	Total	922,705

* In the computer printout, cost items are allocated to waste preparation rather than receiving, size reduction, and storage and recovery cost centers. The total non specific cost were allocated equally to the three cost centers.

TABLE C-45. ORIGINAL CONTRACT CAPITAL COSTS BY COST CENTER

Code	Description	Cost
Receiving		
(333)	Start excavation receiving bldg.	6,755
	Complete excavation receiving bldg.	6,755
	Foundations receiving bldg. footings	85,410
	Complete footings and walls	152,741
	Pour slabs receiving bldg.	113,728
(335)	Install scale bldg.	3,243
	Erect receiving bldg. steel	81,066
	Complete siding etc. -receiving bldg.	87,822
(337)	Start conveyor gallery steel	41,580
	Continue gallery steel	40,533
(350)	Install receiving bldg. arch spec.	29,319
	Non specific costs	307,568
	Total	956,520
Size Reduction		
(220)	2 shredder motors and starters	32,865
(337)	Shredder house and galary siding	39,587
	Install shredder house steel	23,313
	Non specific costs	307,568
	Total	403,333
Storage and Recovery		
(336)	Install storage and recovery unit	189,153
(337)	Start transfer house steel	6,755
	Complete transfer house steel	6,755
	Non specific costs	307,569
	Total	510,232

TABLE C-45. (Continued)

Code	Description	Cost
Thermal Processing		
(110)	Final drawings	3,937
	Complete concrete dwgs, scope	29,399
	Complete steel design	35,955
	Complete ductwork design	3,973
	Complete design	18,673
(220)	Duct work	79,897
	Butterfly valve	11,377
	Local instruments	39,684
	Misc. steel	127,253
(332)	Drive piles as required	70,608
(333)	Start excavations	6,755
(337)	Start install. ductwork	55,932
	Complete ductwork	55,933
	Start piping	68,078
	Complete piping	66,726
	Install refractory unit at ducts	64,177
	Test fuel oil system	6,755
	Install fuel oil line to burners	20,537
(340)	Start above ground electrical	33,777
	Complete above ground electrical	33,777
	Install above ground electrical	33,102
(341)	Install underground power	13,511
(342)	Start instrumentation	23,644
	Complete instrumentation	25,671
(343)	Insulation	28,238
	Painting	24,117
(359)	Final run-ins testing	6,755
	Total	988,241
Energy Recovery		
(110)	Complete concrete dwgs. - scope	15,892
	Final dwgs.	3,973

TABLE C-45. (Continued)

Code	Description	Cost
	Complete steel design	22,646
	Complete ductwork design	3,973
	Complete piping design	23,440
	Scope and spec. steam system	7,946
	Analyze bids and award steam system S/C	1,589
	Analyze bids and award U.G. electrical S/C	0
(220)	Duct work	76,326
	Butterfly valve	64,289
	Jug valve	29,897
	Gate valves	21,430
	Local instruments	50,531
	Misc. steel	13,757
(332)	Drive piles as required	7,552
(333)	Start excavations	4,053
	Complete excavations	4,053
(335)	Erect water treatment bldg. structural steel	5,404
	Complete water treat. bldg. roofing, steel, & siding	6,755
	Complete steel siding on control house	10,809
(337)	Start ductwork	54,168
	Complete ductwork	54,170
	Erect misc. steel	5,191
	Complete misc. steel	5,192
	Final align. test group	1,351
	Start piping erection	54,236
	Continue piping	54,236
	Complete piping erection	54,237
	Final piping testing	12,471
	Install above ground steam system lines	40,530
(340)	Start electrical	13,511
	Continue electrical	13,511
	Complete electrical	13,511
(342)	Start instrumentation	22,443
	Continue instrumentation	22,443
	Complete instrumentation	22,443
	Set panel	9,863
	Complete panel hook-ups, check out	22,239
(343)	Insulation	51,342

TABLE C-45. (Continued)

Code	Description	Cost
(344)	Painting	16,754
(345)	Install U.G. stream line to city of Baltimore	973,236
	Install steam line at R.R. trestle	101,332
	Complete & test steam system	27,022
(350)	Complete bldg. trim and control boiler house	17,024
	Complete bldg. trim, etc.	6,755
(359)	Final run-ins testing	20,266
	Total	2,046,770
Residue Separation		
(110)	Complete concrete dwgs. -scope	10,330
	Final drawings	3,973
	Complete receiving bldg. fdn. design	13,905
	Complete residue separation bldg. fdn. design	3,973
	Complete steel design	24,235
	Complete piping design	10,727
(332)	Drive piles as required	9,485
(333)	Start excavations	4,053
	Complete excavations	4,053
	Residue separation bldgs. foundation	22,036
	Complete residue bldg. slab	4,817
(335)	Install bldg. steel skin	6,755
(337)	Erect res. bldg. int. support	6,755
	Complete structural & platform steel	5,979
	Conveyor trim-outs	13,511
	Start piping above ground	11,536
	Complete piping	11,535
	Piping tests	1,351
(340)	Electrical hook-ups	8,107
(341)	Install bldg. underground electrical	2,702
	Install underground power, etc.	9,458
	Grounding	6,755

TABLE C-45. (Continued)

Code	Description	Cost
(342)	Start instrumentation	22,939
	Complete instrumentation	22,939
(343)	Insulation	2,702
(344)	Painting	10,268
(359)	Final run-ins testing	2,702
(220)	Local instruments	22,895
	Misc. steel	15,476
	Total	302,952

General Plant

(110)	Operator training	27,022
	Preliminary engineering flow sheets	14,898
	Final engineering flow sheets	14,898
	Spec. temporary power	0
	Preliminary plant layouts	23,837
	Firm up plant layouts	27,810
	Issue fencing specs. for quotes	3,937
	All risk & performance bonds	64,000
	Soils boring, site topo.	993
	Site preparation & spec. dwgs.	7,350
	Analyze bids & award site prep. subcontract	795
	Prepare piling pkg. specs.	13,508
	Analyze bids & award piling subcontract	795
	Base CPM schedule	13,243
	Analyze bids and award concrete S/C	795
	Complete concrete dwgs.	11,124
	Final dwgs.	3,973
	Preliminary bldgs. fdn. design - scope	0
	Complete sew./cont. bldg. fdn. design	8,740
	Complete maint. bldg. fdn. design	2,980
	Complete office bldg. fdn. design	2,980
	Complete bldgs. pkg.	27,810
	Analyze bids and award bldgs. subcontract	1,192
	Start underground plumbing design	3,973
	Complete underground plumbing design	3,973
	Analyze bids & award job and erection S/C	1,391
	Complete steel design	29,002
	Design platework & charter	66,149

TABLE C-45. (Continued)

Code	Description	Cost
	Spec. control panel & arrangement	7,946
	Instrument list	13,905
	Start loop sheets	9,336
	Complete initial design loop sheets	9,536
	Spec. control valves	11,919
	Panel initiation and trans. specs.	19,586
	Local initiation spec. and dwgs.	18,673
	Back of panel dwgs.	8,939
	Local initiation installation dwgs.	18,871
	Specify insulation package	3,973
	Spec. for painting package	3,973
	Issue specs. for fire protection	1,986
	Issue specs. for final paving-landscaping	3,973
	Complete ductwork support dwgs.	7,946
	Analyze bids and award piping S/C	3,575
	Complete piping design	21,851
	Start underground elec. & grounding design	13,508
	Complete underground elec. & grounding design	13,508
	Start one-line diagram - all areas	6,357
	Complete one-line diagram - all areas	9,535
	Spec. balance of elec. equip. (pwr., ltg.)	173,221
	Prepare motor list	1,986
	Spec. switchgears, transformers, generator	2,304
	Scope & prepare mechanical erection pkg.	3,973
	Operation manuals	26,486
(220)	13.2 Kv/480-277V substation	153,975
	Emergency power supply	16,535
	Main control panel	86,908
	Local instruments	13,890
	Spare parts	250,265
	Equipment platework	48,149
	Office bldg. steel	4,894
	5 motor control centers	47,754
	5 motor starters	25,927
(330)	Grading of site for all areas	290,486
	Install road sub-bases	27,022
	Install parking lot sub-bases	9,458
	Complete dike	2,702
(331)	Install fencing	16,483
(332)	Drive piles as required	9,660

TABLE C-45. (Continued)

Code	Description	Cost
(333)	Install substation foundations slab	9,458
	Start office bldg. foundation	8,053
	Complete office bldg. slab	14,315
	Start maintenance/storage bldg. fdns.	14,389
	Complete maintenance bldg. slabs	32,588
	Balance of equip. conveyors foundations supports	25,394
	Complete pump foundation excavation	1,351
	Control/water treat. bldg. fnd.	39,108
	Excavation stations	1,351
	Control/water treat. bldg. int. slabs	29,218
(335)	Erect control house steel	9,458
	Erect office bldg. steel siding	56,746
	Storage/maint. bldg. struct. steel erect	16,078
	Complete bldg. exterior	12,160
(337)	Underground sewers	13,999
	Complete piping, tanks and pumps	39,809
	Erect conveyor support	14,092
	Install plumbing	6,458
	Erect agitators	196
	Install plumbing	4,324
(338)	Install cont./water treat. O/G sewers & water	13,999
	Install underground fire loop and test	39,234
	Install underground process water	20,007
	Install monitors	0
	Complete backfill tests	2,702
(341)	Install cont./water treat. U/G elect.	13,511
	Install primary underground feeders	24,320
	Set 4.16 KV equipment	4,053
	Set 480 V equipment	6,755
	Complete 4.16 KV equipment	13,511
	Complete 480V connections	13,511
	Start site lighting	16,213
	Continue site lighting	16,213
(342)	Start instrumentation	12,194
	Complete instrumentation	12,194
(343)	Insulation	10,133

TABLE C-45. (Continued)

Code	Description	Cost
(344)	Painting	6,755
(346)	Install permanent roads	33,102
	Install permanent parking lot	9,458
(347)	Landscaping	46,208
(350)	Complete bldg., interior trim	4,729
	Install office furniture	6,755
	Complete bldg. trim	26,887
(352)	Mobilize on site & set-up temporary facilities	79,039
(359)	Complete final punch lists	432
	Total	2,575,602

TABLE C-46. SUPPLEMENTAL AGREEMENT CAPITAL COSTS BY COST CENTER

Receiving	
Storage pit sump pumps	\$ 1,900
Direct costs	6,500
Indirect costs	5,356
Total	13,756
Size Reduction	
Shredders	171,000
Dust collectors	7,920
Shredder feed conveyors	2,100
Direct costs	0
Indirect costs	115,411
Total	296,431
Storage and Recovery	
Storage and recovery unit	39,976
Dust collectors	11,880
Storage and recovery sump pump	2,300
Shredded refuse conveyors	1,300
Direct costs	1,100
Indirect costs	36,058
Total	92,614
Thermal Processing	
Refuse combustion air fan	13,000
Kiln combustion air fan	26,500
Induced draft fan	77,300
Cooling water system	33,800
Kiln	702,300
Gas purifier	125,050
Scrubber pumps	10,600
Caustic pump	2,000
Seal tank	20,400
Residue quench tank	4,600
Gas scrubber	294,100
Clarifier	2,900
Ram feeders	59,300
Screw conveyors	25,500
Residue quench tank conveyor	194,300
Direct costs	13,700
Indirect costs	1,023,511
Total	2,628,861

TABLE C-46. (Continued)

Energy Recovery	
Waste heat boilers	181,250
Fly ash blower	500
Sulfuric acid pump	100
Degasifier	100
Direct costs	19,900
Indirect costs	128,692
Total	330,542
Residue Separation	
Thickener	600
Magnetic metal separation system	2,700
Glassy aggregate screen	400
Vacuum filter	2,100
Char transfer conveyors	1,500
Roto screen oversize conveyors	3,800
Residue flotation conveyor	3,300
Direct costs	500
Indirect costs	9,500
Total	24,400
General Plant	
Instrument air compressor	31,100
Dust collection fan	200
Direct costs	223,824
Indirect costs	162,657
Total	417,781
Grand Total	3,804,385

APPENDIX D

KILN MODEL COMPUTER PROGRAM

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PROGRAM KILNWA
  DIMENSION BTEMP(100),TTEMP(100),BMVM(100),BTAVE(100),TTAVE(100),T1
  IME(200),BTP(100),TTR(100),BMEVM(100),BMW(100),TMW(100)
  2,QCBT(100),QCTB(100),BMCU(100),TCS(100),CHTC(100)
  3,TMCU2(100),BWE(100),BAMASS(100),BMEW(100),BMASH(100),CHTR(100)
  4,BMEC(100)
  DIMENSION EXAIRF(100),TGCDF(100),TGCDF(100)
  1,TGWF(100),QCRFD(100),TMD2(100),TRU2F(100),TMN2(100),EXAIRV(100)
  2,TGCOVM(100),BXASH(100),BXC(100),BXVM(100),BXW(100),QSAV(100)
  3,TGCH4(100),TGC2H6(100),TGCVM(100),TGH2V(100),TRCARB(100)
  4,TRHYD(100),RMDLCD(100),RMDLVM(100),RMDLW(100)
  5,TRD2V(100),RMDLD2(100)
  6,TGVM(100),TRVM(100),QCRVM(100),
  7,TRU2VM(100),EXAIRC(100),TGCDC(100),TRCC(100),TGCDC(100),QCRCC(1
  800),TRD2(100),TMC2H6(100),TMCH4(100),TMVM(100),TMCU(100),
  9,THM2(100),TMC(100),THASS(100),TXD2(100),TXW(100),TXH2(100)
  DIMENSION TXCD2(100),TXCD(100),TXVM(100),TXCH4(100),
  1,TXC2H6(100),TXN2(100),TXC(100),QCRT(100),BHASH(100),BHVM(100),
  2,BHW(100),BHC(100),THCD(100),THCD2(100),THD2(100),THH2(100),THW(100)
  3,BHEC(100),BHEVM(100),THVM(100),THC2H6(100),THCH4(100),THN2
  4(100),TGCDF(100),BHEW(100)
  5,QEMITS(100),QEMITB(100),QEMITT(100),QABST(100)
  6,QABSEB(100),QABSET(100),ENBALT(100),ENBALB(100),QABSB(100)
  7,THC(100),BMC(100),TRWV(100),TTSVE(100),BTSVE(100)
  REAL RMCU(100)
  INTEGER HAFN,OUT,XNNN
  ITALK=2
  OUT=66
  INPUT=67
  ITERA=0
  IF(ITALK.NE.1)GO TO 1001
  WRITE(OUT,5)
  5 FORMAT(/T5, 'HOW MANY CUBIC ELEMENTS FOR THIS ANALYSIS ? (5<N<100)
  1')
  1001 READ(INPUT,30)N
      HAFN=N/2
      NX=N+10
      IF(ITALK.NE.1)GO TO 1002
      WRITE(OUT,10)
  10 FORMAT(/T5, 'WHAT IS THE REFUSE FEED RATE (TPH) ?')
  1002 READ(INPUT,20)AMASIN
      IF(AMASIN.EQ.0.)AMASIN=AMASHR
      AMASS=AMASIN*.556
  C AMASS IS NOW IN POUNDS PER SECOND
      IF(ITALK.NE.1)GO TO 1003
      WRITE(OUT,105)
  105 FORMAT(' ', 'WHAT IS MAKE UP OF REFUSE:',/T10, 'MOISTURE ? VOLITILES
  1 ? COMBUSTIBLES ? AND ASH ? (IN PERCENTAGES)')
  1003 READ(INPUT,113)AWATIN,AVMIN,ACOMIN,ASHIN
      IF(AWATIN.EQ.0.)AWATIN=AWATR
      AWATER=AWATIN*AMASS/100.
      IF(AVMIN.EQ.0.)AVMIN=AVMS
      AVM=AVMIN*AMASS/100.
      IF(ACOMIN.EQ.0.)ACOMIN=ACOMS
      ACOMB=ACOMIN*AMASS/100.
      IF(ASHIN.EQ.0.)ASHIN=ASHS
      ASH=ASHIN
      ASH=ASH/100.*AMASS
  113 FORMAT(4F10.3)
      IF(ITALK.NE.1)GO TO 1004

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      GOTO 116
360  WRITE(OUT,362)
362  FORMAT(/T5,'THIS KILN REQUIRES APPROX. 20000 CFM.')
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116 IF(ITALK.NE.1)AIRI=20000.
 IF(ITALK.NE.1)GOTO 119
 WRITE(OUT,115)

115 FORMAT(/T5,'WHAT IS THE AIR INPUT (CFM); RELATIVE HUMIDITY; AND
 TEMPERATURE ?')

1004 READ(INPUT,120)AIRI,W2,T
 IF(AIRI.EQ.0.)AIRI=AIRS

119 AIR=AIRI
 TMAIR=AIR*.00125
 TAMB=T+460.
 W2=W2*.008/65.

20 FORMAT(F10.3)
 AVEL=AMASS/(AROH*PIE*DIA**2./8.)
 ARDTV=ARUT*PIE*DIA/60.
 ASQRT=SQRT(4*AVEL**2+(ARDTV/50.)**2)
 ALONGT=(ALONG/(2.*AVEL))*ASQRT
 BSIDE=2.*ALONGT/V

30 FORMAT(I2)
 IF(ITALK.NE.1)GO TO 1005
 WRITE(OUT,35)

35 FORMAT(/T5,'WHAT IS THE AVERAGE TEMP. OF THE OUTSIDE KILN WALL ?
 1 (DEGREES F)')

1005 READ(INPUT,160)ATOWI
 IF(ATOWI.EQ.0.)ATOWI=ATWAVS
 ATWAVG=ATOWI+460.
 IF(ITALK.NE.1)GO TO 1006
 WRITE(OUT,45)

45 FORMAT(/T5,'WHAT ARE THE INITIAL TEMPERATURES:')

50 FORMAT(/T15/'REFJSE OUT OF RAM ? RESIDUE ? FIRE HOOD
 1 ? OFF GASES ?')

1006 READ(INPUT,113)T1,T2,T3,T4

120 FORMAT (3F13.3)
 IF(T1.EQ.0.)T1=T1S
 IF(T2.EQ.0.)T2=T2S
 IF(T3.EQ.0.)T3=T3S
 IF(T4.EQ.0.)T4=T4S
 T1=T1+460.
 T2=T2+460.
 T3=T3+460.
 T4=T4+460.
 TTEMP(NX+2)=(T3+TAMB)/2.
 TTEMP(NX)=T3
 BTEMP(11)=T1
 BTEMP(NX+1)=T2
 NN=NX+1
 NNN=NN+1
 BTEMP(NN+2)=(BTEMP(NN)+TAMB)/2.
 DO 130 I=13,NN,2

130 BTEMP(I)=BTEMP(I-2)+((T2-T1)/HAFN)
 TTEMP(10)=T4
 TTEMP(NX)=T3
 TTEMP(NNN+2)=TAMB
 DO 140 II=12,NX,2
 I=NX-II+12

140 TTEMP(I)=TTEMP(I+2)-((T3-T4)/HAFN)
 IF(ITALK.NE.1)GO TO 1007

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        WRITE(OUT,155)
155  FORMAT(/T5,'WHAT IS THE FEED RATE OF FUEL OIL ? (GAL/MIN DEFAULT
      1=0.3)')
1007  READ(INPUT,160)AFUELI
      IF(ITALK.NE.1)GOTO 1008
      WRITE(OUT,634)
634   FORMAT(/T2,'WHAT VALUES FOR:BMIN,TMIN,BMAX,TMAX ?')
1008  READ(INPUT,635)BMIN,TMIN,BMAX,TMAX
635   FORMAT(4F8.2)
      IF(AFUELI.EQ.0.)AFUELI=AFUELS
160   FORMAT(F4.3)
      AFUEL=AFUELI
      AFUEL=AFUEL*.1
      STOICH=4.76*(AFUEL*3.43+AVM*1.18+ACOMB*2.67)
99    XAIR=(TMAIR-STOICH)/STOICH*100.
      ITERA=ITERA+1
111   FORMAT(/,T15,'THIS IS THE START OF ITERATION NO. ',I2)
      BMVM(11)=AVM
      BMASH(11)=ASH
      BMW(11)=AWATER
      BMCO(11)=ACOMB
      IF(ITERA.GT.10)GOTO 900
      LOOP=1
      IF (ITERA.EQ.1)GOTO 117
118   WRITE (OUT,111)ITERA
      LOOP=0
      ATW=(ALOG(DIA/DINS))*DIA*(ATWAVG-TAMB)/
      1(2.*RESIST)+ATWAVG
      TMW2=TMAIR*W2
      DO 600 I=12,NX,2
      I=NX-I+12
      QSAV(I)=ABS(TTAVE(I)-BTAVE(I-1))
      QCRT(I)=.22*(QSAV(I)**(4./3.))
      IF(BTAVE(I-1).LT.TTAVE(I))QCRT(I)=-QCRT(I)
600   QCTB(I-1)=-QCRT(I)
      DO 300 I=11,NN,2
      BMEC(I)=BMCO(I)*(BTAVE(I)/3400.-.1764)
      IF(BTAVE(I).LE.700.)BMEC(I)=0.
      IF(BTAVE(I).GE.4000.)BMEC(I)=BMCO(I)
      BMCO(I+2)=BMCO(I)-BMEC(I)
300   CONTINUE
      DO 100 I=11,NN,2
      BMASH(I)=BMASH(11)
      BMVM(I+2)=BMVM(I)-.45*.00012*BMVM(11)*TIME(I)*EXP(-.0001*TIME(I))
      1*(1.297)*(705.-BTAVE(I))/(617.-BTAVE(I))
      IF (BMVM(I+2).LE.0.)GOTO 18
      GOTO 17
18    IF(BTAVE(I).LE.760.)BMVM(I+2)=BMVM(I)-.45*.5*.00012*BMVM(11)*TIME
      1(I)*EXP(-.0001*TIME(I))
      IF(BTAVE(I).GE.1800.)BMVM(I+2)=BMVM(I)-.45*1.2*.00012*BMVM(11)*TI
      ME(I)*EXP(-.0001*TIME(I))
      IF(BMVM(I+2).LT.0.)BMVM(I+2)=0.
17    BMEVM(I)=BMVM(I)-BMVM(I+2)
      IF(BMEVM(I).LT.0.)BMEVM(I)=0.
100   CONTINUE
      DO 220 I=11,NN,2
16    TCS(I)=.24+.45*W2
      CHTC(I)=.01*TMAIR**.8/BSIDE**.2
      IF(TTR(I+1)-BTR(I).NE.0.)GOTO 305
      J=I+1

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      CHTR(I)=.173
      GOTO 307
305  CHTR(I)=((TTR(I+1)/100.))**4-(BTR(I)/100.))**4*.173/(TTR(I+1)-BTR(I)
      1))
307  BWE(I)=((TCS(I)/WHFG)*((TTAVE(I+1)-550.))+CHTR(I)*EMISS*(TTR(I+1)-5
      150.))/CHTC(I)+WPB)/(1+(TCS(I)/WHFG*.0015)*(1+CHTR(I)*EMISS/CHTC(I)
      2))
      IF(BWE(I).LT.0..AND.I.EQ.11)BWE(I)=AWATER
      IF(BWE(I).LT.0.)BWE(I)=0.
      BMEW(I)=BWE(I)*THAIR*.4
      BMW(I+2)=BMW(I)-BMEW(I)
      IF(BMW(I+2).LE.0.)BMEW(I)=BMW(I)
      IF(BMW(I+2).LE.0.)BMW(I+2)=0
      BAMASS(I)=BMVM(I)+BMW(I)+BMCO(I)+BMASH(I)
220  CONTINUE
C VOLATILIZATION OF FIXED CARBON
C MASS BALANCE OF CARBON IN BOTTOM ELEMENTS
      DO 302 I=11,NN,2
      BXASH(I)=BMASH(I)/BAMASS(I)
      BXC(I)=BMCO(I)/BAMASS(I)
      BXVM(I)=BMVM(I)/BAMASS(I)
      BXW(I)=BMW(I)/BAMASS(I)
302  CONTINUE
C COMBUSTION OF FUEL OIL
      TMO2(NX+2)=.21*(THAIR-W2*THAIR)
      TMN2(NX+2)=.79*(THAIR-W2*THAIR)
      NNN=NX+2
      EXAIRF(NX+2)=(THAIR-AFUEL*3.43)*100./(AFUEL*3.43)-W2
      IF(EXAIRF(NX+2).GT.150.)EXAIRF(NX+2)=150.
      IF(EXAIRF(NX+2).LT.0.)GO TO 360
      TMW2=W2*THAIR
      TMC2H6(NX+2)=0.
      TMC2H6(NX)=0.
      TMCH4(NX+2)=0.
      TMCH4(NX)=0.
      TMVM(NX+2)=0.
      TMVM(NX)=0.
      TMCO(NX+2)=0.
      TMCO(NX)=0.
      TMCO2(NX+2)=0.
      TMCO2(NX)=0.
      TMH2(NX+2)=0.
      TMH2(NX)=0.
      DO 405 II=12,NX,2
      I=NNN-II+10
      RMCO(I)=10.**(-9.)*EXP(.00587*TTAVE(I))
      TGCOF(I)=(84.*RMCO(I)*AFUEL*EXAIRF(I+2)**.4832)/109.76
      TGCO2F(I)=44.*AFUEL/14.-TGCOF(I)*1.57
      IF(I.NE.NX)TGCO2F(I)=0.
      IF(I.NE.NX)TGCOF(I)=0.
      TGWF(I)=18.*AFUEL*EXAIRF(I+2)/(150.*14.)
      EXAIRF(I)=EXAIRF(I+2)
      IF(I.NE.NX)TGWF(I)=0.
      IF(I.EQ.NX)QCRFO(I)=19350.*AFUEL
      IF(I.NE.NX)QCRFO(I)=0.
      TRD2F(I)=TMO2(I+2)-16.*TGCOF(I)/28.-32.*TGCO2F(I)/44.
      IF(TRD2F(I).LE.0.)TRD2F(I)=0.
      TMN2(I)=TMN2(NX+2)
      EXAIRV(I)=((TRD2F(I)+2.5*BMVM(I-1)/172.)/32-8.5)/8.5*100.
      IF(EXAIRV(I).GT.150.)EXAIRV(I)=150.

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      IF(EXAIRV(I).LT.0)GO TO 380
      TGCQVM(I)=238.*R4CU(I)*EXAIRV(I)**.4832*BMEVM(I-1)/172.
      GO TO 350
380   TGCQVM(I)=(238.*BMEVM(I-1)/172.)*(-.483*EXAIRV(I)/25000.-.483*(EX
      AIRV(I)**2)/2500000.)*(TTAVE(I)-1000.)
      IF(TTAVE(I).LE.1000.)TGCQVM(I)=0.
350   CONTINUE
      IF(TGCQVM(I).LT.0.)TGCQVM(I)=0.
      IF(EXAIRV(I).LT.-100.)TGCQVM(I)=0.
410   TMASS(NX+2)=TMAIR+AFUEL
C   METHANE GENERATION -----VM
      TGCH4(I)=(16.*8.5*BMEVM(I-1)/172.)*(TTAVE(I)
      1*.003/2000.-.0045)*EXAIRV(I)
      IF(EXAIRV(I).GE.0)TGCH4(I)=0.
      IF(EXAIRV(I).LT.-100.)TGCH4(I)=0.
      IF(TTAVE(I).GE.3000.)TGCH4(I)=0.
      IF(TGCH4(I).LT.0.)TGCH4(I)=0.
C   ETHENE GENERATION
      TGC2H6(I)=.1*TGCH4(I)
C   CARBON FROM VOLATILE MATTER (VM)
      TGCVM(I)=(8.5*BMEVM(I-1)*12./172.)*(0.0064*TTAVE
      1(I)*(-50.-EXAIRV(I))/1000.)
      IF(TTAVE(I).GT.3000.)TGCVM(I)=(11.386)*10.**(-3.)*BMEVM(I-1)
      1*(-EXAIRV(I)-50.)
      IF(EXAIRV(I).GT.-50.)TGCVM(I)=0.
C   HYDROGEN FROM VM
      IF(EXAIRV(I).LT.-100.)TGCVM(I)=0.
      TGH2V(I)=(17./172.)*(.00642-TTAVE(I)*.00000642)
      1*EXAIRV(I)*BMEVM(I-1)
      IF(TTAVE(I).GT.3000.)TGH2V(I)=17.*EXAIRV(I)*BMEVM(I-1)/172.*.01284
      IF(EXAIRV(I).GE.0.)TGH2V(I)=0.
      IF(TTAVE(I).LE.1000.)TGH2V(I)=0.
      IF(EXAIRV(I).LT.-100.)TGH2V(I)=0.
      TRD2V(I)=TRD2F(I)-TGCQVM(I)*16./28.
      IF(TRD2V(I).LT.0.)TRD2V(I)=0.
      IF(TRD2V(I).LT.0.)TGCQVM(I)=28.*TRD2F(I)/16.
      TRCARB(I)=72.*BMEVM(I-1)/172.-12.*TGCQVM(I)/28.-TGCVM(I)-12.*
      1TGCH4(I)/16.-24*TGC2H6(I)/30.
      IF(TRCARB(I).LT.0.)GO TO 403
427   TRHYD(I)=10.*BMEVM(I-1)/172.-TGH2V(I)-4.*TGCH4(I)/16.-6.*
      1TGC2H6(I)/30.
      IF(TRHYD(I).LE.0.)GO TO 777
      IF(TRHYD(I).GT.0.)GO TO 783
403   TRCARB(I)=72.*BMEVM(I-1)/172.-12.*TGCQVM(I)/28.-12.*TGCH4(I)/16.-
      124.*TGC2H6(I)/30.
      IF(TRCARB(I).GE.0.)TGCVM(I)=TRCARB(I)
      IF(TRCARB(I).GE.0.)GO TO 427
      TRCARB(I)=0.
      TGCH4(I)=(72.*BMEVM(I-1)/172.-12.*TGCQVM(I)/28.)/.833
      IF(TGCH4(I).LT.0.)TGCH4(I)=0.
      TGC2H6(I)=.1*TGCH4(I)
      IF(TGC2H6(I).LT.0.)TGC2H6(I)=0.
      TRCARB(I)=0.
      TGCVM(I)=0.
      GO TO 427
777   TRHYD(I)=0.
      TGH2V(I)=BMEVM(I-1)/17.2-4.*TGCH4(I)/16.-6.*TGC2H6(I)/30.
      IF(TGH2V(I))778,778,779
778   TGH2V(I)=0.
      TGCH4(I)=BMEVM(I-1)/4.655

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TGC2H6(I)=.1*TGC4(I)
779 RMOLW(I)=0.
  RMOLVM(I)=0.
  IF(TRCARB(I).EQ.0.)GO TO 791
  RMOLCO(I)=TRCARB(I)/12.
  RMOLU2(I)=(TRO2V(I)-32.*RMOLCO(I))/32.
  IF(RMOLU2(I).LT.0.)GO TO 792
  GO TO 480
783 IF(TRCARB(I).LE.0.)GO TO 793
  IF (TRO2V(I).LE.0.)GO TO 907
  IF(TRO2V(I).GT.TRHYD(I)) GO TO 785
  IF (TRO2V(I).GT.TRCARB(I))GO TO 786
  RMOLVM(I)=TRO2V(I)/480.
  GO TO 415
907 RMOLVM(I)=0.
  RMOLW(I)=0.
  RMOLCO(I)=0.
  RMOLU2(I)=0.
  TRCARB(I)=TGCVM(I)+TRCARB(I+2)
  TGH2V(I)=TGH2V(I)+TRHYD(I)
  GO TO 480
791 RMOLCO(I)=0.
  RMOLU2(I)=TRO2V(I)/32.
  GO TO 480
792 RMOLU2(I)=0.
  RMOLCO(I)=TRO2V(I)
  TGCVM(I)=TGCVM(I)+TRCARB(I)-12.*RMOLCO(I)
  GO TO 480
793 IF(TRO2V(I).EQ.0.)GO TO 794
  RMOLVM(I)=0.
  RMOLCO(I)=0.
  RMOLU2(I)=(TRO2V(I)-16.*RMOLW(I))/32.
  IF(RMOLU2(I).LT.0)GO TO 795
  GO TO 480
794 RMOLCO(I)=0.
  RMOLU2(I)=0.
  RMOLW(I)=0.
  RMOLVM(I)=0.
  TGCVM(I)=TGCVM(I)+TRCARB(I)
  GO TO 480
785 IF(TRHYD(I).GT.TRCARB(I))GO TO 786
  RMOLVM(I)=TRHYD(I)/20.
  GO TO 415
786 RMOLVM(I)=TRCARB(I)/144.
415 RMOLW(I)=TRHYD(I)/2.-5.*RMOLVM(I)
  RMOLCO(I)=TRCARB(I)/12.-6.*RMOLVM(I)
  RMOLU2(I)=TRO2V(I)/32.-28.125*RMOLVM(I)-2.*RMOLW(I)-RMOLCO(I)
  IF(RMOLU2(I).GE.0.)GO TO 480
  RMOLU2(I)=0.
  RMOLVM(I)=3.*TRHYD(I)+32.*TRCARB(I)/12.-TRO2V(I)
  IF(RMOLVM(I).GE.0.)GO TO 481
  RMOLVM(I)=0
  GO TO 482
481 RMOLCO(I)=TRCARB(I)/12.-RMOLVM(I)*6.
  RMOLW(I)=TRHYD(I)/2.-5.*RMOLVM(I)
  GO TO 480
482 RMOLVM(I)=0.
  RMOLCO(I)=TRCARB(I)/12.-6.*RMOLVM(I)
  RMOLW(I)=TRHYD(I)/2.-5.*RMOLVM(I)
  RMOLU2(I)=TRO2V(I)/32.-28.125*RMOLVM(I)-2.*RMOLW(I)-RMOLCO(I)

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      IF(RMOLQ2(I).GE.0.)GO TO 480
      RMOLQ2(I)=0.
      GO TO 480
795  RMOLW(I)=TRQ2V(I)/16.
      TGH2V(I)=TGH2V(I)+TRHYD(I)-2.*RMOLW(I)
C   FINAL CALCULATION FOR CO2,H2O,O2 AND VM(C6H10O5)
480  TGCQ2V(I)=RMOLQ2(I)*44./28.
      IF(TGCQ2V(I).LT.0.)TGCQ2V(I)=0.
      TGVV(I)=RMOLW(I)*18.
      IF(TGVV(I).LT.0.)TGVV(I)=0.
      TRQ2V(I)=RMOLQ2(I)*32.
      TRVM(I)=RMOLVM(I)*172.
C   CALCULATIONS FOR HEATS OF COMBUSTION FROM VM
      QCRVM(I)=6189.*(BMEVM(I-1)-TRVM(I))
C   CALCULATION OF EXCESS AIR AFTER VM COMBUSTION
      TRQ2VM(I)=TRQ2V(I)-16.*TGVV(I)/18.-32.*TGCQ2V(I)/44.
      IF(TRQ2VM(I).GE.0.)GO TO 490
      TRQ2VM(I)=0.
      TGCQ2V(I)=44.*TRQ2V(I)/32.-44.*TRVV(I)/36.
490  IF(TGCQ2V(I).GE.0.)GO TO 500
      TGCQ2V(I)=0.
      TGVV(I)=36.*TRQ2V(I)/32.
      IF(TGVV(I).LT.0.)TGVV(I)=0.
C   COMBUSTION OF FIXED CARBON
500  EXAIRC(I)=(TRQ2V(I)/32.-1.)*100.
      IF(EXAIRC(I).LT.-100.)EXAIRC(I)=-100.
      IF(EXAIRC(I).GT.150.)EXAIRC(I)=150.
      CTTAVE=TTAVE(I)
      IF(TTAVE(I).GT.3000.)CTTAVE=3000.
      IF(EXAIRC(I).GT.0.)GO TO 520
501  TGCDC(I)=(28.*BMEC(I-1)/12.)*(0.933*EXAIRC(I)/25000.-.933*(EXAIRC(I)
      )**2/2500000.)*(CTTAVE-1000.)
      IF(EXAIRC(I).LE.-100)GO TO 520
      IF(EXAIRC(I).GT.0.)GO TO 510
      TRCC(I)=BMEC(I-1)*(-EXAIRC(I)/100.-(EXAIRC(I)+100.))
      IF(TTAVE(I).GT.3000.)TRCC(I)=TRCC(I)*2000./(TTAVE(I)-1000.)
      TGCDC(I)=(28.*BMEC(I-1)/12.)*(0.933*EXAIRC(I)/25000.-.933*(EXAIRC(I)
      )**2/2500000.)*(TTAVE(I)-1000.)
      IF(TTAVE(I).GE.3000.)TGCDC(I)=TGCDC(I)*2000./(TTAVE(I)-1000.)
      IF(TRCC(I).LT.0.)TRCC(I)=0.
      IF(TGCDC(I).LT.0.)TGCDC(I)=0.
      GO TO 512
520  TRCC(I)=BMEC(I-1)
      TGCDC(I)=0.
      TGCDC(I)=0.
      GO TO 513
510  TRCC(I)=0.
      IF(EXAIRC(I).GT.150.)EXAIRC(I)=150.
      TGCDC(I)=(28.*BMEC(I-1)/12.)*RMCO(I)*(CEXAIR**.4832)
512  TGCDC(I)=(BMEC(I-1)-TRCC(I)-12.*TGCDC(I))*44./12.
C   HEAT OF COMBUSTION OF CARBON
513  QCR(I)=49940.*TGCDC(I)/(28.*1.055)+178650.*TGCDC(I)/(44.*1.055)
C   OXYGEN REMAINING IN ITH ELEMENT AFTER COMBUSTION OF CARBON
C   ,VM, AND FUEL OIL
      TRQ2(I)=TRQ2VM(I)-32.*TGCDC(I)/44.-16.*TGCDC(I)/28.
      TMO2(I)=TRQ2(I)
      IF(TMO2(I).LT.0.)TMO2(I)=0.
      TMW(I)=TMW(I+2)+TGVV(I)+TGVV(I)+BMEW(I-1)
      TMC(NX+2)=0.
      TMC(I)=TMC(I+2)+TRCC(I)+TGCVM(I)

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IF(TMC(I).LT.0.)TMC(I)=0.
TMH2(I)=TMH2(I+2)+TGH2V(I)
IF(TMCO2(I+2).LE.0.)TMCO2(I+2)=0.
IF(TGCO2C(I).LE.0.)TGCO2C(I)=0.
IF(TGCO2V(I).LE.0.)TGCO2V(I)=0.
IF(TGCO2F(I).LE.0.)TGCO2F(I)=0.
IF(TGCO2C(I).LE.0.)TGCO2C(I)=0.
IF(TGCO2V(I).LE.0.)TGCO2V(I)=0.
IF(TGCO2F(I).LE.0.)TGCO2F(I)=0.
IF(TGCO2C(I).LE.0.)TGCO2C(I)=0.
IF(TGCO2V(I).LE.0.)TGCO2V(I)=0.
IF(TGCO2F(I).LE.0.)TGCO2F(I)=0.
IF(TGCH4(I).LT.0.)TGCH4(I)=0.
IF(TGC2H6(I).LT.0.)TGC2H6(I)=0.
TMCO2(I)=TMCO2(I+2)+TGCO2C(I)+TGCO2V(I)+TGCO2F(I)
TMC(I)=TMC(I+2)+TGCO2C(I)+TGCO2V(I)+TGCO2F(I)
TMCH4(I)=TMCH4(I+2)+TGCH4(I)
TMC2H6(I)=TMC2H6(I+2)+TGC2H6(I)
TMVM(I)=TMVM(I+2)+BMEVM(I-1)+BMEC(I-1)+BMEW(I-1)-TMN2(I)-
1TMH2(I)-TMCH4(I)-TMC2H6(I)-TMCO2(I)-TMC(I)-TMW(I)-TMO2(I)
C CALCULATION OF SPECIES IN TOP---PERCENT
TMASS(I)=TMO2(I)+TMW(I)+TMH2(I)+TMC(I)+TMCO2(I)+TMVM(I)+
1TMCH4(I)+TMC2H6(I)+TMN2(I)+TMC(I)
TXO2(I)=TMO2(I)/TMASS(I)
TXW(I)=TMW(I)/TMASS(I)
TXH2(I)=TMH2(I)/TMASS(I)
TXCO2(I)=TMCO2(I)/TMASS(I)
TXC(I)=TMC(I)/TMASS(I)
TXVM(I)=TMVM(I)/TMASS(I)
TXCH4(I)=TMCH4(I)/TMASS(I)
TXC2H6(I)=TMC2H6(I)/TMASS(I)
TXN2(I)=TMN2(I)/TMASS(I)
TXC(I)=TMC(I)/TMASS(I)
C TOTAL HEAT RELEASE FROM COMBUSTION
QCRT(I)=QCRFO(I)+QCRG(I)+QCRVM(I)
IF(QCRT(I).LT.0.)QCRT(I)=0.
C ENTHALPY VALUES OF SPECIES---BOTTOM ELEMENTS(SOLIDS)
C TOP ELEMENTS(GASES)
THCO(I)=TMC(I)*(.226+.000032*TTEMP(I))*TTEMP(I)
THCO2(I)=TMCO2(I)*(.186+.0000625*TTEMP(I))*TTEMP(I)
THO2(I)=TMO2(I)*(.2+.0000353*TTEMP(I))*TTEMP(I)
THH2(I)=TMH2(I)*(3.35+.000114*TTEMP(I))*TTEMP(I)
THW(I)=TMW(I)*(WHFG+WHF+(.433+.0000166*TTEMP(I))*(TTEMP(I)
1-672.))
THVM(I)=TMVM(I)*(.087*(TTEMP(I)-500.))+100.)
THC(I)=TMC(I)*(.2*(TTEMP(I)-1500.))+100.)
THC2H6(I)=TMC2H6(I)*(4.01+.01636*TTEMP(I))*TTEMP(I)/30.
THCH4(I)=TMCH4(I)*(.208+.000561*TTEMP(I))*TTEMP(I)
THN2(I)=TMN2(I)*(.227+.0000292*TTEMP(I))*TTEMP(I)
405 CONTINUE
C CALCULATION OF RADIATION HEAT TRANSFER TERMS BASED ON THE
C HOTTEL COHEN DATA AND TECHNIQUE
BKA=6.
TKA=.06
BK=BKA*BSIDE
TK=TKA*BSIDE
BPSI=EXP(-.41*BK**.643)
TPSI=EXP(-.41*TK**.643)
FSGO2=.1667
FSG12B=.033*EXP(-BKA*.355*BSIDE)
FSG12T=.033*EXP(-BKA*.355*BSIDE)
FSG22B=.004*EXP(-1.435*BKA*BSIDE)
FSG22T=.004*EXP(-1.435*TKA*BSIDE)

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FSG32B=.03*EXP(-1.1*2.04*BSIDE)
FSG32T=.03*EXP(-1.1*4.02*BSIDE)
FSG13T=.02*EXP(-1.361*4.02*BSIDE)
FSG13B=.02*EXP(-1.361*2.04*BSIDE)
FSG11B=.0135*EXP(-1.007*3.03*BSIDE)
FSG11T=.0135*EXP(-1.007*3.03*BSIDE)
FSG10B=.033*EXP(-.355*3.03*BSIDE)
FSG10T=.033*EXP(-.355*3.03*BSIDE)
FGG01B=.11*EXP(-.497*BKA*BSIDE)
FGG01B=.11*EXP(-.497*3.03*BSIDE)
FGG02B=.022*EXP(-1.454*BKA*BSIDE)
FGG12B=.017*EXP(-1.688*3.03*BSIDE)
FGG11B=.045*EXP(-.787*3.03*BSIDE)
FGG01T=.11*EXP(-.497*TKA*BSIDE)
FGG01T=.11*EXP(-.497*3.03*BSIDE)
FGG02T=.022*EXP(-1.454*TKA*BSIDE)
FGG11T=EXP(-.787*3.03*BSIDE)
FGG12T=.017*EXP(-1.688*3.03*BSIDE)
C HEAT EMITTED
DO 550 I=11,NX,1
  QEMITS(I)=FMISS*SIGMA*(BSIDE**2)*(ATW**4)
550 CONTINUE
C ENTHALPY OF INCOMING AIR
  THD2(NX+2)=TMD2(NX+2)*(.2+.0000353*TTEMP(NX+2))*TTEMP(NX+2)
  THW2=TMW2*(WHFG+WHF+(.433+.0000166*TTEMP(NX+2))*(TTEMP(
  1NX+2)-672.))
  THN2(NX+2)=TMN2(NX+2)*(.227+.0000292*TTEMP(NX+2))*TTEMP(NX+2)
  DO 560 I=11,NN,2
    BHASH(I)=BMASH(I)*.15*BTEMP(I)
    BHVM(I)=BMVM(I)*.035*BTEMP(I)
    BHW(I)=BMW(I)*BTEMP(I)
    BHC(I)=BMC(I)*BTEMP(I)*.5
    BHEW(I)=BMEW(I)*(WHFG+WHF+(.433+.0000166*BTAVE(I))*(BTAVE(I)-672.
    1))
    BHEC(I)=BMEC(I)*(.2*(BTAVE(I)-1500.))+100.)
    BHEVM(I)=BMEVM(I)*(.087*(BTAVE(I)-500.))+100.)
    QEMITB(I)=.004*(BSIDE**2)*BK*SIGMA*BPSI*(ATR(I)**4)
560 CONTINUE
  DO 570 I=12,NX,2
    QEMITT(I)=.004*(BSIDE**2)*BK*SIGMA*TPSI*(TTR(I)**4)
570 CONTINUE
C ABSORS=BED RADIATION FROM SIDES
  DO 580 I=11,NN,2
    IF(I.LE.11.)QEMITS(I-2)=QEMITS(11)
    IF(I.LE.13.)QEMITS(I-4)=QEMITS(11)
    IF(I.GE.NX-3)QEMITS(I+4)=QEMITS(NX-1)
    IF(I.GE.NX-1)QEMITS(I+2)=QEMITS(NX-1)
    QASB(I)=3.*FSG02*QEMITS(I)+3.*FSG12B*(QEMITS(I+2)+QEMITS(I-2))
    1+2.*FSG10B*QEMITS(I)+3.*FSG22B*(QEMITS(I+4)+QEMITS(I-4))+FSG32B
    2*QEMITS(I)+FSG13B*(QEMITS(I+2)+QEMITS(I-2))+2.*FSG11B*
    3(QEMITS(I+2)+QEMITS(I-2))
580 CONTINUE
  DO 590 I=12,NX,2
    IF(I.LE.12.)QEMITS(I-2)=QEMITS(12)
    IF(I.LE.14.)QEMITS(I-4)=QEMITS(12)
    IF(I.GE.NX)QEMITS(I+2)=QEMITS(NX)
    IF(I.GE.NX-2)QEMITS(I+4)=QEMITS(NX)
    QABST(I)=3.*FSG02*QEMITS(I)+3.*FSG12T*(QEMITS(I+2)+QEMITS(I-2))
    1+2.*FSG10T*QEMITS(I)+3.*FSG22T*(QEMITS(I+4)+QEMITS(I-4))
    2+FSG32T*QEMITS(I)+FSG13T*(QEMITS(I+2)+QEMITS(I-2))

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      3+2.*FSG11T*(QEMITS(I+2)+QEMITS(I-2))
590  CONTINUE
C HEAT ABSORBED FROM ADJACENT ELEMENTS
      DO 605 I=11,NN,2
      IF(I.LE.11.)QEMITT(I-1)=QEMITT(12)
      IF(I.LE.11.)QEMITT(I-3)=QEMITT(12)
      IF(I.LE.11.)QEMITB(I-2)=QEMITB(11)
      IF(I.LE.11.)QEMITB(I-4)=QEMITB(11)
      IF(I.LE.13.)QEMITT(I-3)=QEMITT(12)
      IF(I.LE.13.)QEMITB(I-4)=QEMITB(11)
      IF(I.GE.NX-3.)QEMITT(I+5)=QEMITT(12)
      IF(I.GE.NX-3.)QEMITT(I+4)=QEMITT(12)
      IF(I.GE.NX-1.)QEMITB(I+2)=QEMITB(11)
      IF(I.GE.NX-1.)QEMITB(I+4)=QEMITB(11)
      IF(I.GE.NX-1.)QEMITT(I+3)=QEMITT(12)
      IF(I.GE.NX-1.)QEMITT(I+5)=QEMITT(12)
      QABSEB(I)=FSG01B*(QEMITB(I+2)+QEMITB(I-2))+FSG01B
      1*QEMITT(I+1)+FSG02B*(QEMITB(I-4)+QEMITB(I+4))
      2+FSG11B*(QEMITT(I+3)+QEMITT(I-1))+FSG12B*
      3(QEMITT(I-3)+QEMITT(I+5))
605  CONTINUE
      DO 610 I=12,NX,2
      IF(I.EQ.NX)QEMITT(I+2)=QEMITT(NX)
      IF(I.EQ.NX)QEMITT(I+4)=QEMITT(NX)
      IF(I.EQ.NX)QEMITB(I+1)=QEMITB(NX-1)
      IF(I.EQ.NX)QEMITB(I+3)=QEMITB(NX-1)
      IF(I.EQ.NX-2.)QEMITB(I+3)=QEMITB(NX-1)
      IF(I.EQ.NX-2)QEMITT(I+4)=QEMITT(NX)
      IF(I.EQ.12.)QEMITT(I-2)=QEMITT(12)
      IF(I.EQ.12.)QEMITT(I-4)=QEMITT(12)
      IF(I.EQ.12)QEMITB(I-3)=QEMITB(11)
      IF(I.EQ.12)QEMITB(I-5)=QEMITB(11)
      IF(I.EQ.14)QEMITB(I-5)=QEMITB(11)
      IF(I.EQ.14)QEMITT(I-4)=QEMITT(12)
      QABSET(I)=FSG01T*(QEMITT(I+2)+QEMITT(I-2))+FSG01T*
      1QEMITB(I-1)+FSG02T*(QEMITT(I+4)+QEMITT(I-4))+FSG11B*(QEMITB(I-3)
      2+QEMITB(I+1))+FSG12B*(QEMITB(I+3)+QEMITB(I-5))
610  CONTINUE
C ENERGY BALANCE
      DO 620 I=12,NX,2
      ENBALT(I)=QABSET(I)+QABST(I)-QEMITT(I)+QCRT(I)+QCBT(I)
      1+THCO(I+2)-THCO(I)+THCO2(I+2)-THCO2(I)+THO2(I+2)-THO2(I)
      2+THCH4(I+2)-THCH4(I)+THC2H6(I+2)-THC2H6(I)+THW(I+2)
      3-THW(I)+THC(I+2)-THC(I)+THVM(I+2)-THVM(I)+THH2(I+2)
      4-THH2(I)+THN2(I+2)-THN2(I)+BHEW(I-1)+BHEC(I-1)+BHEVM(I-1)
620  CONTINUE
      WRITE(OUT,141)
141  FORMAT(/T10,'ENERGY BALANCES (BTU)',/T2,'ELEMENT',T11,'BOT.',T22,
      1'ELEMENT',T35,'TOP')
      DO 630 I=11,NN,2
      I1=I-10
      I2=I-9
      ENBALB(I)=QABSEB(I)+QABSB(I)-QEMITB(I)+QCTB(I)+BHASH(I)
      1-BHASH(I-2)+BHW(I)-BHW(I-2)+BHVM(I)-BHVM(I-2)
      2+BHC(I)-BHC(I-2)-RHEC(I)-BHEW(I)-BHEVM(I)
      WRITE(OUT,151)I1,ENBALB(I),I2,ENBALT(I+1)
151  FORMAT(T4,I2,T10,F7.1,T25,I2,T33,F7.1)
630  CONTINUE
      ENBALB(NX+1)=ENBALB(NX-1)
      ENBALT(NX+2)=ENBALT(NX)

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ENBALT(10)=ENBALT(12)
ENBALT(8)=ENBALT(10)
ENBALB(NX+3)=ENBALB(NX+1)
ENBALB(9)=ENBALB(11)
CONVER=5000.
TEST=0.
DO 800 I=1,NX
IF (ABS(ENBALB(I)).LE.CONVER)GO TO 750
TEST=1.
IF (ABS(ENBALB(I-2)).LE.CONVER)GO TO 720
BALAN=(ENBALB(I)+ENBALB(I-2))/(2.*.172*BAMASS(I))
IF (BALAN.LT.BMIN)BALAN=BMIN
IF (BALAN.GT.BMAX)BALAN=BMAX
BTEMP(I)=BTEMP(I)+BALAN
GO TO 730
720 BALAN=ENBALB(I)/(.172*BAMASS(I))
IF (BALAN.LT.BMIN)BALAN=BMIN
IF (BALAN.GT.BMAX)BALAN=BMAX
BTEMP(I)=BTEMP(I)+BALAN
730 IF (ABS(ENBALB(I+2)).LE.CONVER)GO TO 740
BALAN=(ENBALB(I)+ENBALB(I+2))/(2.*.172*BAMASS(I+2))
IF (BALAN.LT.BMIN)BALAN=BMIN
IF (BALAN.GT.BMAX)BALAN=BMAX
BTEMP(I+2)=BTEMP(I+2)+BALAN
BTEMP(I)=(BTEMP(I)+BTEMP(I+2))/2.
GO TO 750
740 BALAN=ENBALB(I)/(.172*BAMASS(I+2))
IF (BALAN.LT.BMIN)BALAN=BMIN
IF (BALAN.GT.BMAX)BALAN=BMAX
BTEMP(I+2)=BTEMP(I+2)+BALAN
BTEMP(I)=(BTEMP(I)+BTEMP(I+2))/2.
750 CONTINUE
IF (ABS(ENBALT(I)).LE.CONVER)GO TO 800
TEST=1.
IF (ABS(ENBALT(I-2)).LE.CONVER)GO TO 770
BALAN=(ENBALT(I)+ENBALT(I-2))/(2.*.25*TMASS(I))
WRITE(OUT,123)BALAN,I
123 FORMAT(T2,'AFTER 750 BALAN=',F8.2,' FOR I=',I2)
IF (BALAN.LT.TMIN)BALAN=TMIN
IF (BALAN.GT.TMAX)BALAN=TMAX
TTEMP(I)=TTEMP(I)+BALAN
GO TO 780
770 BALAN=ENBALT(I)/(.25*TMASS(I))
WRITE(OUT,124)BALAN,I
124 FORMAT(T2,'AFTER 770 BALAN=',F8.2,' FOR I=',I2)
IF (BALAN.LT.TMIN)BALAN=TMIN
IF (BALAN.GT.TMAX)BALAN=TMAX
TTEMP(I)=TTEMP(I)+BALAN
780 IF (ABS(ENBALT(I+2)).LE.CONVER)GO TO 790
BALAN=(ENBALT(I)+ENBALT(I+2))/(2.*.25*TMASS(I+2))
WRITE(OUT,125)BALAN,I
125 FORMAT(T2,'AFTER 780 BALAN=',F8.2,' FOR I=',I2)
IF (BALAN.LT.TMIN)BALAN=TMIN
IF (BALAN.GT.TMAX)BALAN=TMAX
TTEMP(I+2)=TTEMP(I+2)+BALAN
TTEMP(I)=(TTEMP(I)+TTEMP(I+2))/2.
GO TO 800
790 BALAN=ENBALT(I)/(.25*TMASS(I+2))
WRITE(OUT,126)BALAN,I
126 FORMAT(T2,'AFTER 790 BALAN=',F8.2,' FOR I=',I2)

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      IF(BALAN.LT.TMIN)BALAN=TMIN
      IF(BALAN.GT.TMAX)BALAN=TMAX
      TTEMP(I+2)=TTEMP(I+2)+BALAN
      TTEMP(I)=(TTEMP(I)+TTEMP(I+2))/2.
800  CONTINUE
      WRITE(OUT,802)ITERA
802  FORMAT(/T5,'TEMPERATURES',T20,'ITERATION NO.',I2,/T2,'ELEMENT',T
111,'BOT.',T22,'ELEMENT',T35,'TOP')
      DO 806 I=11,NX,2
      I1=I-9
      J=I-10
      WRITE(OUT,151)J,BTEMP(I),I1,TTEMP(I+1)
806  CONTINUE
C  DIAM WAS 20, ALONG WAS 100, DINS WAS 18.5
      DATA ARDH/15./,DIA/20./,ALONG/100./,AMASHR/30./,AROT/1./,
1AFUELS/.30/,FUELQ/19580./,FUELQX/1./,ACOMS/.0669/,COMBQ/14000./,
2COMBQX/1./,AVMS/.3754/,VMQ/1500./,VMQX/1./,C/90000./,ASH
3S/.00071/,PIE/3.1416/,AWATR/.2/,ALEANS/.5/,TWDAYS/18.5/,AVAPS/12./
4,WHFG/1150./,T1S/150./,T2S/1800./,T3S/1600./,T4S/1600./,WPB/12./
5,RESIST/.45/,DINS/18.5/,EMISS/.75/,SIGMA/4.76E-13/,WHF/180./
6,AIRS/20000./,VERG/.1/
117 DO 110 I=10,NNN,2
      TTAVE(I)=(TTEMP(I)+TTEMP(I+2))/2.
      TTR(I)=((TTEMP(I)**4+TTEMP(I+2)**4)/16.)**(1./4.)
110 CONTINUE
      DO 109 I=11,NN,2
      BTSAVE(I)=BTAVE(I)
      BTAVE(I)=(BTEMP(I)+BTEMP(I+2))/2.
      TIME(I)=BSIDE*(I-9)/8./AVEL
      BTR(I)=(((BTEMP(I)**4+BTEMP(I+2)**4)/16.))**(1./4.)
109 CONTINUE
      IF(ITERA.EQ.1.AND.LOOP.EQ.1)GOTO118
      IF(ITERA.NE.1)GOTO 121
      WRITE(OUT,11)AMASS
      WRITE (OUT,21) AWATER,AVM,ACOMB,ASH
      WRITE(OUT,31)AIR,TMAIR,W2,AVEL,AROTV,ALONG,BSIDE
11  FORMAT(/T5,'REFUSE=',T25,1F10.3,' LBS./SEC.')
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21 FORMAT(/T5,'MASS OF WATER=',T25,1F10.3,' LBS./SEC.',/T5,'MASS OF V
10LATILES=',T25,1F10.3,' LBS./SEC.',/T5,'MASS OF COMBUSTIBLES=',T2
15,1F10.3,' LBS./SEC.',/T5,'MASS OF ASH=',T25,1F10.3,' LBS./SEC.')

31 FORMAT(/T5,'AIR=',T25,1F8.1,' CFM',/T5,'AIR MASS=',T25,1F8.1,' LBS
1./SEC.',/T5,'MOISTURE=',T25,1F8.5,' LBS./SEC.',/T5,'MASS VELOCITY
2=',T25,1F8.5,' FT./SEC.',/T5,'ROT VEL=',T25,1F8.5,' RPM',/T5,'KIL
3N LENGTH=',T25,F8.2,' FEET',/T5,'ELEMENT DIMENSION=',F10
4.5,' UNITS')

51 FORMAT(/T2,'AVG. TEMPERATURES OF TOP ELEMENTS ARE (DEG. R):',/T2
1,8F10.3)

61 FORMAT(/T2,'BOTTOM AVG. TEMPERATURES ARE (DEG. R):',/T2,8F10.3)

121 WRITE(OUT,51)(TTAVE(I),I=12,NX,2)
WRITE(OUT,61)(BTAVE(I),I=11,NX,2)

122 WRITE(OUT,128)

128 FORMAT(/T3,'ANALYSIS OF KILN OFF GAS:')

WRITE(OUT,8)(I,TXO2(I+10),TXH2(I+10),TXC(I+10),TXN2(I+10),TXCO(
11+10),TXCO2(I+10),TXW(I+10),TXVM(I+10),TXCH4(I+10),TXC2H6(I+10)
2,TMASS(I+10),I=2,N,2)

8 FORMAT(/T5,'ELEMENT ',I2,/T8,'% OXYGEN=',T27,2P1F6.3,T36,'% HYDRO
1GEN=',T55,2P1F6.3,/T8,'% CARBON=',T27,2P1F6.3,T36,'% NITROGEN=
1',T55,2P1F6.3,/T8,'% CARBON MONOXIDE=',
1T27,2P1F6.3,T36,'% CARBON DIOXIDE=',T55,2P1F6.3,/T8,
3,'% MOISTURE=',T27,2P1F6.3,T36,'% VOLATILES=',T55,2P1F6.3,/T8,


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      4'% METHANE=',T27,2P1F6.3,T36,'% ETHANE=',T55,2P1F6.3,/T30,'MASS='
      5,0P1F8.3)
      WRITE(OUT,129)
129  FORMAT(/T3,'ANALYSIS OF KILN RESIDUE:')
      WRITE(OUT,127)(I,BXC(I+10),BXVM(I+10),BXW(I+10),BXASH(I+10)
      1,BAMASS(I+10),I=1,N,2)
127  FORMAT(/T5,I2,'% CARBON=',2P1F6.3,'% VOLATILES=',2P1F6.3,'%
      1 MOISTURE=',2P1F6.3,'% ASH=',2P1F6.3,/T30,'MASS=',0P1F8.3)
      WRITE(OUT,36)
36  FORMAT(/T2,'I',3X,'THASS',5X,'TMO2',5X,'TMW',4X,'TMH2',4X,'TMC0'
      1,3X,'TMC02',4X,'TMVM',3X,'TMCH4',3X,'TMC2H6',3X,'TMN2',4X,'TMC')
      XNNN=NNN-10
      WRITE(OUT,34)(I,THASS(I+10),TMO2(I+10),TMW(I+10),TMH2(I+10),TMC
      10(I+10),TMC02(I+10),TMVM(I+10),TMCH4(I+10),TMC2H6(I+10),TMN2(I+
      210),TMC(I+10),I=2,XNNN,2)
34  FORMAT(T2,I2,11F8.4)
      IF(TEST.EQ.1.)GOTO 99
      WRITE(OUT,901)
901  FORMAT(/T2,'***** NORMAL COMPLETION OF KILN *****')
900  STOP
      END

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